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STUDIES ON THE FOOD AND FEEDING RELATIONSHIPS OF THE INSHORE FISHES OFF CALICUT ON THE MALABAR COAST

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Introduction

The importance of the study of the food of fishes with its bearings on the different aspects of their biology like shoaling and migratory habits, feeding adaptations, growth, etc., is well known and considerable work has been done on this subject abroad since the close of the last century. Though very little was known hitherto about the food of fishes in Indian seas, there has been some addition to our knowledge in recent years. Some of the earlier papers dealing with the subject are on the food of *Sardinella longiceps* (Hornell and Nayudu, 1924), *S. gibbosa* (Devanesan, 1932) and perches of the Madras coast (Job, 1940). Chidambaram and Venkataraman (1946) and Devanesan and Chidambaram (1948), in their accounts of the marine food fishes of the west coast and common food fishes of the Madras Presidency respectively, have given brief notes about their food. Chacko (1949), in his account of the food and feeding habits of the fishes of Gulf of Mannar, has given a historical resume of the papers pertaining to the food of fishes in Indian waters published till then. Since then Bapat and Bal (1950, 1952) have investigated the food of some young clupeids and other fishes from Bombay waters and Bhimachar and George (1952) have observed in detail the seasonal fluctuations in the food of mackerel, *Rastrelliger canagurta*. Prabhu (1950), Nair (1951, 1952) and Bapat *et al.* (1951) have briefly reported on the food of the ribbon fish (*Trichiurus haumela*), the sardines (*Kowala coval* and *Sardinella longiceps*) and the Bombay duck (*Harpodon nehereus*) respectively. Pillay (1952) has given a critical review of the methods employed for the qualitative and quantitative estimation of the food of fishes. Some of the more recent contributions on the food of fishes are by Vijayaraghavan (1951, 1953), Sarojini (1954), Kuthalingam (1955, 1956), Karekar and Bal (1958) and Tampi (1958). The present author (1956) in a paper on the biology of the common anchovy, *Thrissocles mystax*, has mentioned in detail the different food items encountered in its stomach and their fluctuations in the stomach contents during different periods of the

year. Mention may be made here of the observations of Kow (1950) on the food and feeding relationships of the fishes of Singapore Straits which is of special interest as it bears considerable similarity to the present investigation.

The present communication relates to the investigation carried out during the years 1948–53 on the food and feeding habits of some common fishes obtained from the inshore region off Calicut on the Malabar coast.

Material and Methods

The study was based on material obtained from the bi-weekly departmental fish catches made at a depth of 2–8 fathoms in the inshore region off Calicut during the years 1948–53. But the bulk of the data presented in this paper is drawn from the examination of the specimens obtained during the year 1952–53. The catches were obtained by the boat-seine and the gill net, the two common nets used along this coast. The specimens which were usually caught in the morning hours were immediately brought to the laboratory and analysed for their species, size and sex. For the size, the total length of the fish from the tip of the snout to the end of the longest ray of the caudal fin was measured. The intensity of feeding was recorded basing the state of distension of stomach and the amount of food contained in it, as follows: E = 'empty' when the stomach was empty, P = 'poor' when the stomach contained a little food and was not distended, M = 'medium' when the stomach was half-full and was slightly distended, G = 'good' when the stomach was full and distended, H = 'heavy' when the stomach was gorged with food and was fully distended. The stomach contents were carefully removed and examined in fresh condition as far as possible or else preserved in 5% formalin for subsequent study. The food elements were identified as far as possible up to species or up to the genus or family, depending upon the completeness of the organism and the extent of digestion. If the digestion had progressed to an advanced stage and the food organism was mixed with large quantities of mucus making identification difficult, it was treated as digested matter.

The state of maturity of gonads was generally determined following the maturity scales fixed by the International Council for the Exploration of the Seas, taking into consideration the size and colour of the gonads.

In evaluating the different food organisms the *points method* of Swynnerton and Worthington (1940), as reviewed by Haynes (1950), with some modifications was followed. Under this method, the different food items were either counted or assessed by eye and listed under the categories swarms,

plenty, common, few, little and rare; due consideration being given to the size of the food organism as well as its abundance. Points 50, 40, 30, 20, 10 or 5 were allotted to each category. Points were allotted to the stomachs also depending upon the degrees of their fullness and the points gained by each food item were either proportionately increased or decreased to the total allotted to the stomach and then summed up. The summations of the points obtained by each food item for each month were then scaled down to percentages to show the composition of the food items for different months. This method is essentially a volumetric one and was preferred to many others as it had the advantage of giving roughly both the quantitative and qualitative data without the need for very detailed counts.

The following example will explain how the method works: The stomach of one fish is full and contains three prawns, six polychætes and fifty cladocerans. The prawns, as they are greater in volume, are put in the category of 'plenty' and are given 40 points, the polychætes, whose bulk is less than that of prawns, are put in the category of 'common' and given 30 points, and the cladocerans, though more numerous than prawns and polychætes, are lesser in volume and hence put in the category of 'little' and given 10 points. The total comes to 80. Since the stomach is full, it is allotted 40 points and the points allotted to each of the food items are scaled down proportionately to bring the total to 40. It works out as follows: Prawns 20, polychætes 15 and cladocerans 5. The stomach of another fish contains the same food in the same proportions, but is half-full. A half-full stomach gets 20 points and the points allotted to each of the food items work out to: prawns 10, polychætes 7 and cladocerans 3.

Analysis of the Food of Different Species

During the course of the present studies the stomach contents of 7,328 specimens belonging to the following 47 species were examined.

Dussumieria hasselti Bleeker

This fish is fairly common in the inshore waters off Calicut during November–February. A total of 145 specimens of size 129–162 mm. were examined of which 77 contained empty stomachs.

The intensity of its feed was poor during the greater part of the year inasmuch as out of a total of 145 specimens examined 53% had empty stomachs. This is in agreement with the findings of Kow (1950) who has also noticed the same feature in the specimens of this species caught from Singapore Straits. It is seen from Fig. 1 *a*, that the sergestid, *Lucifer*,

formed favourite food, as it was dominant practically during all the months. Prawns formed a significant portion of the feed from November–January while teleosts occurred in the stomach contents in good quantities only in January. Heavy feeding on the stomatopod, *Squilla*, was noticed in February. Copepods and crab megalopa were also observed in its stomach, the former in November and the latter in January.

Sardinella fimbriata (C. & V.)

This forms a major inshore fishery of the region during the post-monsoon and the summer months. In all, 581 specimens measuring 100–177 mm. were examined of which 39 did not contain food in their stomachs.

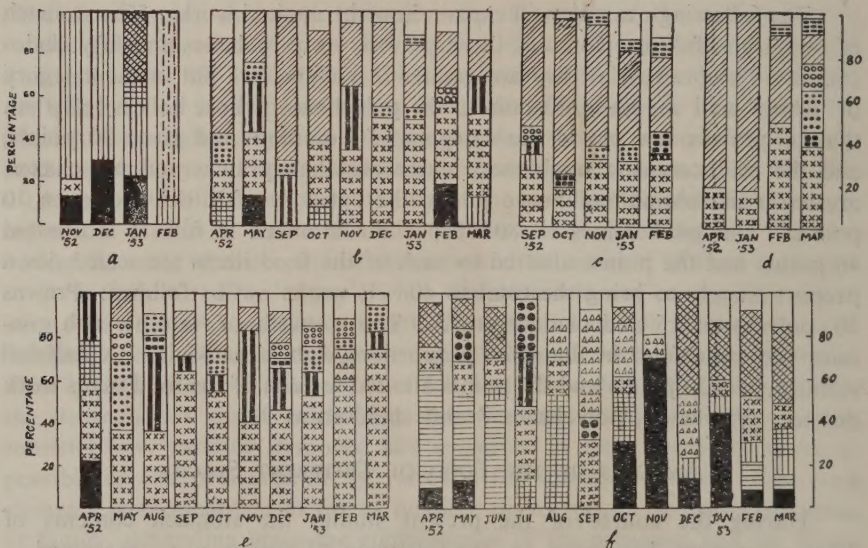

FIG. 1. Percentage composition of different food organisms during April 1952 to March 1953 in the stomach contents of (*a*) *Dussumieria hasselti*; (*b*) *Sardinella fimbriata*; (*c*) *Sardinella longiceps*; (*d*) *Sardinella albella*; (*e*) *Kowala coval* and (*f*) *Opisthopterus tardoore*. (In Figs. 1 to 4, food organisms forming less than 5% have been included in 'others'.)

It is seen from Fig. 1 *b* that the fish is primarily a plankton feeder phytoplankton and copepods constituting the chief items. During September–October, phytoplankton was the most important component showing a peak rise in their percentage occurrence, the commonest species being *Coscinodiscus*, *Fragilaria*, *Nitzschia*, *Ceratium*, *Biddulphia*, *Trichodesmium*, etc., a few of which at times occurred in swarms. Copepods occurred consistently in its stomach and they were generally abundant

during October–March. Some of the common copepods met with were *Temora*, *Acartia*, *Pseudodiaptomus*, *Euterpina* and *Oithona*. The cladocerans, chiefly *Evadne*, formed a conspicuous part of its diet during May, September and November. Some minor food items encountered were small penæids, larval bivalves, decapod and cirripede larvæ, *Lucifer*, fish eggs, etc. The presence of sand grains in the stomach contents on a few occasions may be accidental as there is no evidence of this fish having fed at the bottom.

Sardinella longiceps Val.

This forms a major fishery along this coast and they were obtained in the departmental catches during the months September–February. Out of a total of 150 specimens with a size range of 126–211 mm. examined for the stomach contents, all were found to contain food.

It is seen from Fig. 1 *c* that phytoplankton was the dominant food item, while copepods formed the next important food. Nair (1952) has observed this fish to be a plankton feeder, feeding predominantly on phytoplankton. The present observations show that this item of food was abundant in its stomach contents during the months of September–November, but in the subsequent months of January and February it was less plentiful. Some of the phytoplanktonic forms commonly met with in its stomach were the diatoms, *Fragilaria*, *Coscinodiscus*, *Nitzschia*, *Pleurosigma*, *Biddulphia*, and dinophysids like *Pyrophacus* and *Ornithocercus*. Among the diatoms, *Fragilaria* was common. Copepods occurred during September–February, with slight increase in their abundance from November onwards. Other items observed were cirripede larvæ, larval bivalves, fish eggs, *Evadne*, *Lucifer*, etc. The presence of sand grains in the stomachs of this fish also may be accidental as it is a surface-feeder.

Sardinella albella (C. & V.)

Generally *Sardinella albella* was less abundant in the inshore catches than *S. fimbriata* and *S. longiceps*. 60 specimens of size 125–160 mm. were examined and all contained food in their stomachs.

Phytoplankton (54·91%) constituted the main food of this fish while copepods (36·25%) ranked next in importance (Fig. 1 *d*). Fish eggs, larval bivalves and cirripede larvæ were occasionally observed in its stomach contents in small quantities. Less occasionally sand grains were also met with in its stomach. Vijayaraghavan (1953) found zooplanktonic elements, especially smaller crustaceans like copepods, to predominate in the stomach contents of this fish caught from the Madras coast.

Kowala coval (C.)

This was one of the common species occurring in the inshore area and was obtained in the catches almost all through the year except during the months of June and July. 586 specimens were examined in total of which 113 were found with empty stomachs. Their size range was from 51–120 mm.

It is seen from Fig. 1 *e* that the fish was mainly a zooplankton feeder. Copepods were found to be the more favourite food item forming 49·8% of the total food. They were less plentiful in the stomachs during April, May and August but during September–March, they occurred in abundant numbers in the stomachs. *Pseudodiaptomus*, *Temora*, *Acartia*, *Eucalanus* and *Corycæus* were the common copepods met with. Phytoplankton formed a good portion of its diet during the months of May and September–December. The common phytoplankton forms observed were *Coscinodiscus*, *Fragilaria*, *Nitzschia*, *Rhizosolenia*, *Chætoceros*, *Ceratium* and *Pyrophacus*. *Coscinodiscus* and *Fragilaria* were more plentiful in the stomachs during September, while during October *Nitzschia* and *Rhizosolenia* were more predominant. Cladocerans (chiefly *Evadne*) formed conspicuous part of the food in August and November. Larval bivalves, cirripede larvæ and fish eggs were observed in the stomachs during the greater part of the year. Small quantities of penæid prawns, polychætes and decapod larvæ were also occasionally met with. Nair (1951) has observed this fish to be a plankton feeder, the juveniles preferring the cladoceran, *Evadne*.

Opisthopterus tardoore (C.)

This is another common fish in the inshore waters, occurring almost throughout the year. 712 specimens of size 48–197 mm. were examined f which 62 were with empty stomachs.

A large variety of food organisms was encountered in the stomachs, but the main constituents were penæid prawns, *Acetes*, copepods, fish post-larvæ and polychætes (Fig. 1 *f*). Copepods occurred in the stomachs throughout the year, however, with their percentage values relatively higher during July and September. The common copepods observed were *Pseudodiaptomus*, *Acartia*, *Temora*, *Eucalanus* and *Labidocera*. The maximum occurrence of prawns was in October, November and January. *Acetes* formed the main food during summer months, April and May and the first half of June. Post-larval fishes, especially of *Thrissocles*, *Anchoviella*, *Leiognathus* and *Ambassis* were plentiful in the stomachs during the months December–March. Adult fishes also were encountered at times in the stomachs. Polychætes (mainly *Prionospio pinnata*) were common from August–December,

their maximum occurrence being in September, October and December. Good feeding on amphipods was noticed during May and July. The percentage of decapod larvæ was high during the month of August. *Lucifer* was a common food item from December–March.

Anchoviella tri (Bleeker)

Of the genus *Anchoviella*, *A. tri* alone was contributing considerably to the inshore fishery of the region. They were present in good numbers in the catches during the months of June–March. Of 658 specimens ranging in size from 47–95 mm. examined, 21 were found with empty stomachs.

It is seen from Fig. 2 *a* that the fish is mainly a plankton feeder, with copepods and larval bivalves forming the major constituents of its food.

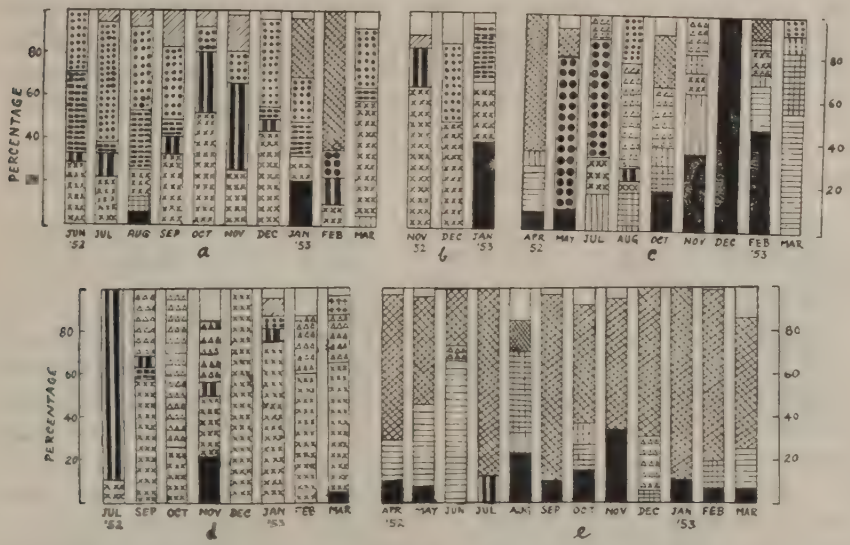

FIG. 2. Percentage composition of different food organisms during April 1952 to March 1953 in the stomach contents of (*a*) *Anchoviella tri*; (*b*) *Anchoviella heteroloba*; (*c*) *Thrissocles malabaricus*; (*d*) *Ambassis gymnocephalus* and (*e*) *Lactarius lactarius*.

The former was present in appreciable numbers in stomach contents during June and July and also from September–March, except, January and February. The commonest copepods observed were *Acartia*, *Pseudodiaptomus*, *Oithona* and *Paracalanus*. Larval bivalves were dominant in the stomachs during June–September, December, January and March. Of the rest, cirripede larvæ and cladocerans were the most frequent, of which the latter was abundant in the stomachs in November. Among the diatoms,

Coscinodiscus was favoured most and occurred in good numbers in September and November. Decapod larvæ, *Lucifer* and crab zœa constituted small proportions of its food. Occasionally it was found to feed on small penæids, fish post-larvæ and amphipods.

Anchoviella heteroloba (Rupp.)

Although *A. heteroloba* contributes, when compared with the previous species, a fishery of lesser importance in the inshore waters, heavy catches were obtained on a few occasions. 193 specimens of size 70–93 mm. were examined, of which 9 had empty stomachs.

It is seen from Fig. 2 *b* that copepods formed a major food constituent, occurring abundantly during all the three months examined. Larval bivalves were in abundance in December while penæid prawns were plentiful in January. Good numbers of cladocerans, mainly *Evadne*, were met with in the stomach contents in November and cirripede larvæ in January. Forming part of its food, at times, were *Lucifer*, fish post-larvæ, crab megalopa and phytoplankton.

Thrissocles malabaricus (Bleeker)

The species, though not as common as *T. mystax*, were obtained in small quantities almost all through the year. 317 specimens of size 71–184 mm. were examined, of which 40 had empty stomachs.

Its food consisted of a wide variety of organisms, the more common forms being penæid prawns, polychætes, copepods, *Acetes*, decapod larvæ and *Lucifer* (Fig. 2 *c*). The prawns were generally abundant during the post-monsoon and summer months. The common species observed were *Parapenæopsis stylifera*, *Penæus indicus* and *Metapenæus dobsoni*. *Acetes* was plentiful during February–April and polychætes during August and October–November. Occasionally, it fed heavily on amphipods, the common species being *Cheiriphotis megacheles*. Forming part of its feed on some occasions were *Hippa*, larval bivalves, *Squilla*, crab megalopa, etc.

Ambassis gymnocephalus (Lac.)

This small fish is the most common perch in the inshore waters off Calicut, though not of much economic importance. It occurred in the catches practically all through the year. Altogether 374 specimens measuring 45–91 mm. were examined of which 27 were with empty stomachs.

It is seen from Fig. 2 *d* that copepods were a very important constituent of its food, their average for the entire period being 52·6%. They were

plentiful in the stomach contents during September–March, with the exception of October and November, when there was a slight decrease in their occurrence. The common copepods recorded were *Centropages*, *Pseudodiaptomus*, *Eucalanus*, *Acartia* and *Oithona*. Polychætes (chiefly *Prionospio pinnata*) also appeared to be a favourite food as they were generally abundant during the post-monsoon months. The cladocerans were most abundant in July, though small quantities were noticed during few subsequent months. Decapods, mainly post-larval and young penæids, were also taken by this fish in small quantities. Cirripede larva was intermittently present in the stomach contents. Diatoms were generally rare. On a few occasions small numbers of *Sagitta*, *Hippa*, amphipods, larval bivalves, fish post-larvæ and fish scales were also met with.

Lactarius lactarius (Bl. &. Schn.)

It is a common fish in the inshore region, small quantities of which were obtained throughout the year. 410 specimens were examined of which 26 had no food in their stomachs. The size ranged from 43–206 mm.

Figure 2 *e* shows that this fish is a carnivore, fish forming the most prominent diet practically during all parts of the year. Post-larvæ and

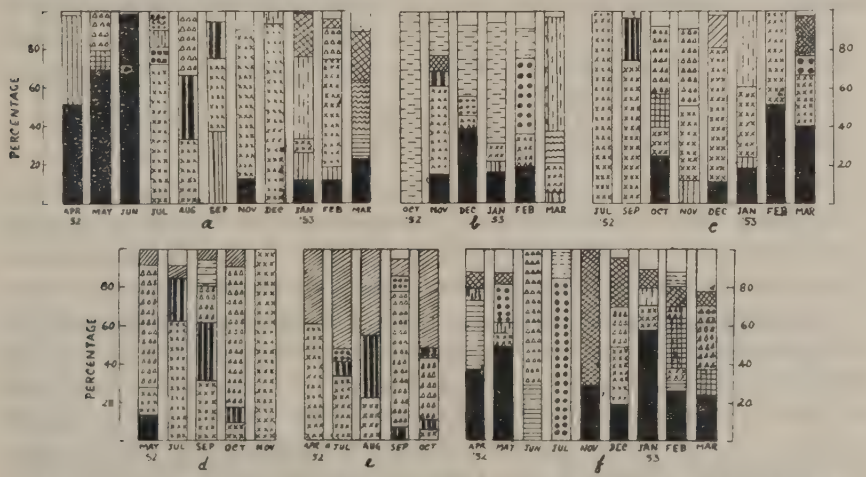

FIG. 3. Percentage composition of different food organisms during April 1952 to March 1953 in the stomach contents of (*a*) *Caranx* (*Selar*) *kalla*; (*b*) *Caranx* (*Selar*) *djedaba*; (*c*) *Leiognathus insidiator*; (*d*) *Leiognathus bindus*; (*e*) *Leiognathus splendens* and (*f*) *Pseudosciæna sina*.

adults of *Thrissocles*, *Leiognathus*, *Anchoviella*, *Cynoglossus*, etc., were noticed in its stomach. Another common item was small and large-sized penæids,

mainly *Parapenæopsis stylifera*, *Penæus indicus* and *Metapenæus dobsoni*. *Acetes* was found plentiful in the stomachs from March to first half of June. Polychætes and decapod larvæ were conspicuous during December and February respectively. Copepods, amphipods, *Lucifer*, *Squilla*, *Hippa*, *Mysis* and cladocerans were also occasionally met with.

Caranx (*Selar*) *kalla* C. & V.

Of the 8 species of carangids recorded in the departmental catches, *C. kalla* was the commonest species. 645 specimens of size range 64–158 mm. were examined and 159 had been found with no food in their stomachs.

Figure 3 *a* shows that copepods formed a chief part of its food during greater part of the year, the common species being *Acartia*, *Centropages*, *Pseudodiaptomus*, *Temora* and *Paracalanus*. Prawns were next in importance, the maximum occurrence of which was from April–June. *Acetes* was observed in March in small quantities. *Lucifer* was found abundant in April and September while Polychætes and cladocerans were plenty in August. Good quantities of fish post-larvæ were found during January and March while on a few occasions fish scales alone were noticed. Heavy feeding on *Squilla* was evident in January while in March the stomachs of a large number of specimens were found gorged with pteropods (chiefly *Creseis* sp.). Other animals met with were mysids, ostracods, crab megalopa, cirripede larvæ and larval bivalves.

Caranx (*Selar*) *djedaba* (Forsk.)

The pattern of occurrence of this fish was more or less similar to that of *C. kalla*, though its fishery is less in magnitude than that of the latter in the inshore waters. 284 specimens were examined in all, of which 106 were with empty stomachs. Their size range was 54–190 mm.

Feeding was observed to be poor in this fish, about 43% of the stomachs being found empty. Its food comprised mainly of prawns and copepods (Fig. 3 *b*). The presence of a large number of fish scales without any trace of the soft or bony parts of the prey on numerous occasions is particularly striking. It may be that the fish is habitually feeding on the offal left over by other fishes. Copepods like *Temora*, *Pseudodiaptomus* and *Centropages* formed a conspicuous part of its food in November while some quantities of penæid prawns were noticed from November–February. It was found also to have fed heavily on amphipods in February, the presence of which along with sand grains showed that it fed at the bottom during this month. The stomachs of all the specimens examined towards the close of March

were found gorged with echiurid worms, a feature observed in the stomachs of many other species during this period. Larval bivalves, fish post-larvæ, cladocerans, decapod larvæ, *Lucifer* and pteropods were noticed in its food on some occasions. Kuthalingam (1955) has found crustaceans to form the main food of this species caught off Madras coast, the same being the case here also.

Leiognathus insidiator (Bl.)

Of the six species of *Leiognathus* obtained in the departmental catches, *L. insidiator* was the most common. In all 354 specimens of size 37–104 mm. were examined, of which 26 did not have any food in their stomachs.

From the high percentage figures noticeable in Fig. 3 *c* it is evident that the fish favoured copepods during greater part of the year. The common species were *Acartia*, *Paracalanus*, *Temora*, *Pseudodiaptomus*, etc. Small penæids also were frequently met with and were next in importance. Polychætes (mainly *Prionospio pinnata*) were dominant in October and November while in January many specimens were found gorged with *Squilla* larvæ. *Evadne*, *Lucifer*, larval bivalves, fish post-larvæ, decapod larvæ, amphipods and diatoms were also observed. Bapat and Bal (1952) have found that polychætes and copepods formed the main food of this fish in its younger stages.

Leiognathus bindus (C. & V.)

This forms a good fishery in some years. 241 specimens measuring 51–114 mm. were examined, of which 36 were without food in their stomachs.

The food, like that of the other species of *Leiognathus*, comprised mainly of copepods and polychætes, supplemented at times by cladocerans and diatoms (Fig. 3 *d*). The maximum occurrence of copepods in the stomach contents was in November, the common ones being *Acartia*, *Centropages*, *Pseudodiaptomus* and *Eucalanus*. Polychætes were abundant in May and October and cladocerans in July and September. Small quantities of diatoms were observed in its food on few occasions. Penæid prawns and fish scales were also noticed in insignificant quantities.

Leiognathus splendens (C.)

This too is a common silver-belly contributing a rich fishery in some years. 173 specimens of size 57–119 mm. were examined, of which 14 were with empty stomachs.

It is seen from Fig. 3 *e* that unlike in other species of *Leiognathus*, diatoms constituted a significant portion of the food of this fish, some of

the common forms being *Fragilaria*, *Nitzschia*, *Coscinodiscus* and *Pleurosigma*. Copepods too formed a good portion of its food in April, July and August. Cladocerans were noticed from July–October with maximum occurrence in August. Good feeding on polychætes took place in September and October as evidenced by the stomachs of a large number of specimens gorged with them. Stray numbers of decapod larvæ, fish eggs and larval bivalves were also recorded in the stomach contents.

Pseudosciæna sina (C. & V.)

This is a common sciænid in this area. 500 specimens of size 43–180 mm. were examined, out of which 39 specimens were found with empty stomachs.

A large variety of organisms was noticed in the stomachs, the chief of which were prawns, polychætes, teleosts, amphipods and *Acetes* (Fig. 3*f*). Prawns were abundant in April and May and from November–March while *Acetes* was plentiful in April and June. Polychætes and adult and post-larval fishes formed a good part of its food during the post-monsoon and summer months while the former alone was abundant in June. At times it was found to feed heavily on amphipods. Some of the other items observed in small quantities were copepods, *Squilla*, *Lucifer*, *Mysis*, *Sagitta*, larval bivalves, echiurid worms and diatoms. The presence of debris comprising of fragments of mud and sand grains indicates their feeding at the bottom.

Johnius belengeri (C. & V.)

This fish was caught in lesser quantities than *P. sina* in the departmental catches. 91 specimens of size 56–173 mm. were examined and six of them were with empty stomachs.

Figure 4*a* shows that prawns and polychætes formed the chief item of its food, *Squilla*, *Acetes*, amphipods and copepods occurring occasionally. Debris and sand grains were observed on some occasions.

Otolithes ruber (Bl. & Schn.)

This fish formed only a minor fishery in the inshore waters. 124 specimens of size 56–253 mm. were examined, out of which 13 were with empty stomachs.

This is mainly a carnivorous fish, teleosteans forming a major item of its food in almost all the months when specimens were examined (Fig. 4*b*). Ranking next in importance were prawns which were plentiful from April–July and again from December–March except February. *Acetes* formed

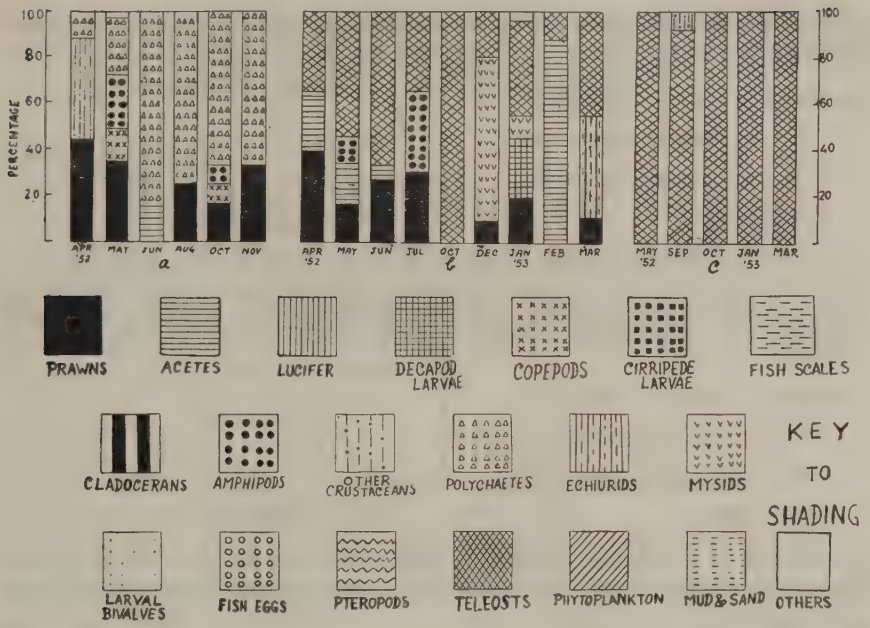

FIG. 4. Percentage composition of different food organisms during April 1952 to March 1953 in the stomach contents of (*a*) *Johnius belengeri*; (*b*) *Otolithes ruber*; (*c*) *Scomberomorus guttatus*.

a significant part of its diet in April, May and February. Large numbers of mysids and echiurid worms were met with in December and March respectively. Amphipods, fish post-larvæ and crab megalopa also formed part of its feed during some months.

Scomberomorus guttatus (Schn.)

Only stray numbers of juvenile specimens of this fish were caught in the departmental catches. 133 specimens of size 136–496 mm. were examined, out of which 86 were with empty stomachs.

The high percentage of empty stomachs may be due to poor feeding of the juvenile fishes in the inshore waters. The probable ejecting of food at the time of capture was not noticed. It was found to feed only on fish and occasionally ostracods (Fig. 4 *c*).

Anodontostoma chacunda (Ham.)

No. of specimens examined	..	64
No. with empty stomachs	..	30
Size range	..	81–163 mm.

A few copepods and diatoms along with bits of digested material and debris were found.

Anchoviella commersonii (Lac.)

No. of specimens examined	.. 41
No. with empty stomachs	.. 1
Size range	.. 54–122 mm.

It was found to feed heavily on larval bivalves. On a few occasions, copepods, amphipods, prawns, crab megalopa, cirripede larvæ and *Evadne* also were noticed. On rare occasions the stomachs were found gorged with polychætes.

Thrissocles purava (Ham.)

No. of specimens examined	.. 16
No. with empty stomachs	.. 1
Size range	.. 114–160 mm.

It fed heavily on prawns, especially during the months of April and May. The other items present in the stomachs were decapod larvæ, amphipods and *Lucifer*.

Thrissocles setirostris (Brouss.)

No. of specimens examined	.. 5
No. with empty stomachs	.. 2
Size range	.. 97–133 mm.

Copepods were present in the stomachs in abundance along with a few cladocerans.

Thrissocles dussumieri (C. & V.)

No. of specimens examined	.. 35
No. with empty stomachs	.. 1
Size range	.. 111–135 mm.

It was found to feed mainly on prawns, copepods and *Lucifer*. Brachyuran larvae, cladocerans and diatoms were also observed in some numbers.

Chirocentrus dorab (Forsk.)

No. of specimens examined	.. 26
No. with empty stomachs	.. 8
Size range	.. 262–476 mm.

On many occasions *Anchoviella heteroloba* and *A. commersonii* were found in its stomach. It is interesting to note its preference to white-baits. On one occasion fragments of prawn were encountered.

Tachysurus dussumieri (C. & V.)

No. of specimens examined	..	13
No. with empty stomachs	..	4
Size range	..	23–145 mm.

Eight stomachs, out of the thirteen examined, were found to be packed with polychætes, while the stomach of one specimen contained large numbers of ophiuroids, bivalves and sea-weeds.

Osteogeneiosus militaris (L.)

No. of specimens examined	..	10
No. with empty stomachs	..	5
Size range	..	91–210 mm.

The stomachs of 5 were gorged with polychætes of the genera *Sternaspis* and *Lumbriconereis*. One prawn was observed in one of the stomachs.

Mugil speigleri Bleeker.

No. of specimens examined	..	11
No. with empty stomachs	..	1
Size range	..	53–180 mm.

The food of this species consisted of diatoms like *Coscinodiscus*, *Fragilaria*, *Pleurosigma*, *Rhizosolenia*, *Cyclotella*, etc., and other algæ and copepods. Sand grains were observed in the stomachs of most of the specimens. The presence of algæ bits and sand grains indicates their browsing habits.

Polydactylus heptadactylus (C.)

No. of specimens examined	..	39
No. with empty stomachs	..	8
Size range	..	77–153 mm.

The food of the species mainly consisted of prawns and polychætes. Copepods, crab megalopa, amphipods, *Lucifer* and *Evadne* also formed part of the food. A medium-sized fish, *Therapon jarbua* was present in the stomach of a specimen caught on 19th June 1952.

Polydactylus plebeius (Brouss.)

No. of specimens examined	.. 42
No. with empty stomachs	.. 15
Size range	.. 99–185 mm.

Most of the specimens examined were found with their stomachs gorged with *Emerita asiatica* which is a common crab occurring in the muddy bottom in the inshore regions.

Eleutheronema tetradactylum (Shaw)

No. of specimens examined	.. 23
No. with empty stomachs	.. 1
Size range	.. 100–285 mm.

The stomachs of this species were usually packed with prawns. Teleosteans formed the next important constituent of its food. Occasionally it was found also to feed heavily on polychætes, the chief of which was *Prionospio pinnata.*

Lutjanus vaigiensis Q. G.

No. of specimens examined	.. 1
Size	.. 167 mm.

The stomach of the only specimen examined contained one fish post-larval *Caranx* (*Caranx*) *sexfasciatus* (Q. G.)

No. of specimens examined	.. 4
No. with empty stomachs	.. Nil
Size range	.. 96–157 mm.

The stomach of one specimen was gorged with *Acetes* while in another a partly digested *Leiognathus* was observed. Fragments of fish, decapod appendages and *Squilla* were noticed in the stomachs of the rest of the specimens.

Megalaspis cordyla (L.)

No. of specimens examined	.. 41
No. with empty stomachs	.. 2
Size range	.. 111–335 mm.

Fish formed the most favourite food of the species and the stomachs of as many as 21 specimens were seen packed with it. 3 partly digested *Anchoviella*

were observed in the stomach of one specimen. It was also found to feed on amphipods, copepods, crab megalopa, *Lucifer* and *Hippa*.

Decapterus russelli (Rupp.)

No. of specimens examined	.. 2
No. with empty stomachs	.. Nil
Size range	.. 154–160 mm.

The stomach of one of the specimens contained some fish scales, copepods and *Evadne* while in the other there were a few fish scales and diatoms like *Fragilaria* and *Coscinodiscus*.

Chorinemus tala (C. & V.)

No. of specimens examined	.. 5
No. with empty stomachs	.. 3
Size range	.. 124–174 mm.

Fragments of decapods were noticed in the stomachs of both the specimens.

Leiognathus ruconius (H. B.)

No. of specimens examined	.. 9
No. with empty stomachs	.. Nil
Size range	.. 53-87 mm.

The analysis of the stomach contents showed that this species was mainly a plankton feeder, copepods, cirripede larvæ and *Evadne* being common. The polychæte, *Prionospio pinnata* was abundant in the stomachs of two specimens.

Leiognathus blochi (C. & V.)

No. of specimens examined	.. 35
No. with empty stomachs	.. 1
Size range	.. 62–109 mm.

This species was found to feed on copepods, small penæids and *Evadne*. Polychætes were occasionally found. In a few specimens, a few fish scales and diatoms like *Coscinodiscus* and *Fragilaria* were noticed.

Pomadasys hasta (Bloch)

No. of specimens examined	.. 12
No. with empty stomachs	.. 4
Size range	.. 75–99 mm.

Polychætes were observed in abundance in the stomachs of 5 specimens, while in the rest a few copepods and *Coscinodiscus* were noticed.

Otolithes argenteus (C. & V.)

No. of specimens examined	.. 39
No. with empty stomachs	.. 1
Size range	.. 92–216 mm.

Penæid prawns and fish formed the main items of food. The common prawns were *Parapenæopsis stylifera* and *Metapenæus dobsoni*. Good numbers of *Acetes* were consumed during March and April. Occasionally polychætes were also seen in their food.

Trichiurus haumela (Forsk.)

No. of specimens examined	.. 31
No. with empty stomachs	.. 7
Size range	.. 262–752 mm.

This is a carnivorous fish and its food was mainly comprised of teleosteans.

Rastrelliger canagurta (Cuv.)

No. of specimens examined	.. 44
No. with empty stomachs	.. Nil
Size range	.. 132–216 mm.

This fish was found to feed exclusively on plankton, both zoo- and phyto-plankton elements being noticed in its stomachs. The common elements were copepods, decapod larvæ, cladocerans, larval bivalves, fish eggs and larvæ, peridinians and diatoms.

Scomberomorus commersonii (Lac.)

No. of specimens examined	.. 9
No. with empty stomachs	.. 7
Size range	.. 138–207 mm.

Teleosteans were seen in both the stomachs with food.

Cybium interruptum C. & V.

No. of specimens examined	.. 14
No. with empty stomachs	.. 11
Size range	.. 150–298 mm.

The stomachs of the three specimens which had food were seen gorged with teleosteans.

Solea ovata Rich.

No. of specimens examined	.. 9
No. with empty stomachs	.. 4
Size range	.. 67–84 mm.

In the stomachs of four specimens, amphipods were found in plenty while in the remaining one numerous copepods were found.

Cynoglossus semifasciatus Day

No. of specimens examined	.. 17
No. with empty stomachs	.. 3
Size range	.. 87–140 mm.

Sand grains and mud fragments were found in plenty in its food which indicates its bottom feeding habits. Polychætes, chiefly *Prionospio pinnata*, were frequently found in its stomach. Amphipods, decapod fragments and diatoms like *Coscinodiscus* and *Fragilaria* were noticed on some occasions.

General Observations

Feeding habits.—From the foregoing analysis of the food, it is evident that the inshore fishes possess diverse feeding habits. Some are plankton feeders, while others are carnivorous or omnivorous. When some are surface-feeders, others feed constantly at the bottom. Again among the plankton feeders, while fishes like *Sardinella longiceps* and *S. albella* have a special favour for phytoplankton elements, those like *Anchoviella* spp., *Dussumieria hasselti* and *Ambassis gymnocephalus* appear to prefer zooplankton and yet others, *viz.*, *S. fimbriata* and *Leiognathus splendens* feed on both phyto and zooplankton without any apparent discrimination. The presence of larger swimming forms like young prawns and polychætes in their stomachs suggests that plankton feeders at times resort also to particulate feeding, though their general feeding habit is by filtration enabled by their gill-rakers.

A large majority of the inshore fishes are carnivores and are cosmopolitan in their tastes. But a few of them like *Lactarius lactarius*, *Chirocentrus dorab*, *Scomberomorus guttatus* and *Trichiurus haumela* and *Pseudosciæna sina*, *Johnius belengeri* and *Opisthopterus tardoore* exhibit chiefly piscivorous and carcinivorous tendencies respectively, inasmuch as fish and crustaceans predominated in their stomachs during greater part of the year. The majority

of the carnivores, excluding those that are chiefly piscivorous, show considerable vertical feeding as evidenced by the presence of surface animals like *Acetes dispar* and fish post-larvæ and benthic forms like bottom dwelling polychætes and amphipods in the stomach contents. The presence of mud and debris in the stomachs of many of these fishes furnishes evidence about their feeding at the bottom. Though none of the carnivores examined show any exclusive vermivorous tendency, worms like polychætes formed often times a significant part of their diet. Only *Mugil speigleri* and *Tachysurus dussumieri* are found to be omnivorous, feeding both on animal and vegetable matter. The soles, *Cynoglossus semifasciatus* and *Solea ovata*, are particularly bottom-feeders as mud and debris along with bottom dwelling polychætes and amphipods were frequently met with in their stomach contents.

Seasonal variation in the food of fishes and its correlation with its availability in the environment.—In order to find out the seasonal variation in the food of the fish population as a whole, a "Food Index" was worked out following the method adopted by Kow (1950). Such food organisms that occurred in abundance or in good numbers in the stomach contents of a particular species of fish were marked by a *plus* sign against the respective species. The food indices were arrived at by calculating the ratio of the totals of the *plus* signs entered against each food organism for each month to the total number of species examined during that month multiplied by 100. As Kow (*op. cit.*) puts it the food index "signifies the level of utilisation of a particular group of food organism by the fish population present in the habitat under consideration". The food indices of different food organisms for each month from April 1952 to March 1953 are shown in Table I and their percentage figures graphically represented in Fig. 5.

The analysis of the food as a whole shows that crustaceans (58·9%) formed the largest group, the others in the order of their importance being teleosts (15·7%), polychætes (9·2%), phytoplankton (8·3%), Molluscs (4·1%) and the rest (3·8%). It is seen from the higher food indices values (Table I) obtained by prawns, *Acetes*, copepods, polychætes and teleosts during March–June that they formed the major food in that period. But in the subsequent months of July and August a considerable decline in the food indices values of prawns and *Acetes* and a significant rise in the values of cladocerans and copepods were noticed. Occasional heavy feeding on polychætes and amphipods was also observed in this period. During September–February, the food indices figures for several food elements including prawns, copepods, polychætes, etc., rose showing a general increase in their feeding activity.

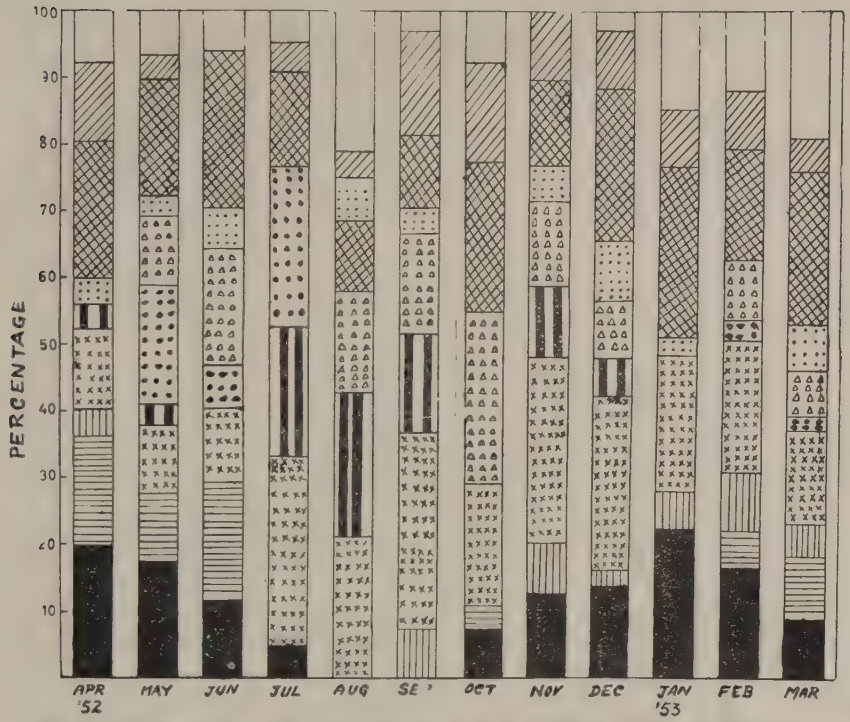

FIG. 5. Histogram showing percentage figures of food indices of different food organisms from April 1952 to March 1953.

It is seen from Fig. 5, that the occurrence of prawns in the stomach contents extended from October–July, the maximum being from January–May when also the prawns have been observed in plenty in the inshore region off Calicut, the species dominant both in the stomach contents and in the area referred to being *Parapenæopsis stylifera*, *Metapenæus dobsoni* and *Penæus indicus* (Bhimachar and Venkataraman, 1952; Menon, 1953). Another common food element is the small shrimp, *Acetes dispar* whose abundant occurrence in the stomachs extended from March–June and correspondingly in the same period this shrimp has been found to occur in plenty in this region (Bhimachar and Venkataraman, *op. cit.*).

During September–February copepods formed a major food of these fishes and a corresponding abundance in the plankton is also noticed at this period (George, 1953). There was a slight decline in their occurrence in the stomachs in the succeeding months of March–June, during which period the copepod fraction in the plankton also declines (George, *op. cit.*

TABLE I

Food indices for different food organisms for each month from April 1952 to March 1953

Main food	1952									1953		
	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Penæid prawns	42	36	22	7	..	..	13	26	29	47	33	25
Acetes	33	21	33	..	..	..	7	..	..	..	11	25
Lucifer	8	..	..	..	..	14	..	16	6	12	17	13
Decapod larvæ	8	..	..	..	9	..	7	..	..	6	11	19
Copepods	25	21	22	43	36	57	33	58	53	42	39	38
Cirripede larvæ	..	..	11	..	9	..	7	..	..	12	6	..
Crab megalopæ	..	7	..	..	9	..	..	..	..	..	..	..
Cladocerans	8	7	..	29	36	29	..	21	12	..	..	6
Sqilla	8	..	..	..	..	..	..	..	..	12	6	6
Hippa	..	..	..	7	9	..	..	..	..	..	..	..
Mysids	..	..	..	..	..	..	..	..	6	..	..	..
Amphipods	..	36	11	29	..	..	..	..	..	..	6	6

Polychætes	..	..	21	33	..	27	29	47	26	18	..	17	19
Echiurids	..	..	..	..	..	..	..	..	..	..	..	..	13
Pteropods	..	..	..	..	..	..	..	..	..	..	..	..	13
Larval bivalves	..	8	7	11	7	18	7	..	11	18	6	..	19
Fish post-larvæ	..	8	7	11	..	..	7	7	..	12	18	11	25
Fish eggs	..	..	7	..	..	..	..	..	..	..	..	..	6
Teleosts	..	33	29	33	21	9	14	33	26	35	35	22	31
Phytoplankton	..	25	7	..	7	9	29	27	21	18	18	17	13

Though copepods are generally scarce in the plankton during the monsoon period, George (*op. cit.*) has observed their sporadic appearance in large numbers in the plankton during the same period and the high values of them seen in July and August can be attributed to their presence in large numbers in the stomachs of *Leiognathus* spp. and *Anchoviella* spp. whose principal season of fisheries is during the rainy months. *Acartia*, *Pseudodiaptomus*, *Temora*, *Eucalanus*, *Euterpina*, *Oithona*, *Centropages* and *Paracalanus* were some copepods commonly met with both in the stomachs and in the plankton.

The fair occurrence of phytoplankton in the stomach contents from September–March coincided with its moderate abundance in the coastal waters in the same period. The slight rise in its food index value in April may be correlated with its minor peak noticed in summer months (George, *op. cit.*). While a phytoplankton bloom is observed during the monsoon months in the coastal waters (George, *op. cit.*: Subrahmanyan, 1959), a corresponding high incidence of phytoplankton in the stomach contents was not noticed, which may be due to the fact that sufficient numbers of major phytoplankton feeders could not be examined. Some of the common diatoms observed both in the plankton and in the stomach contents were *Fragilaria oceanica*, *Nitzschia*, *Coscinodiscus*, *Rhizosolenia*, *Chætoceros* and *Pleurosigma*.

Teleostean fishes, both post-larval and adult forms, which form a major food for many inshore fishes, occurred in the stomachs all through the year, though post-larval ones were more common in the stomach contents during December–June coinciding with their abundant occurrence in the inshore waters during the same period (Bhimachar and Venkataraman, *op. cit.*). The common species met with both in the stomach contents and in the environment were *Thrissocles* spp., *Leiognathus* spp., *Kowala coval*, *Anchoviella tri*, *Ambassis gymnocephalus*, *Pseudosciæna sina*, *Otolithes ruber* and *Cynoglossus semifasciatus*.

Another major food element, polychætes (especially *Prionospio pinnata*) occurred abundantly in the stomachs during September–May in which period they have also been observed in plenty in the inshore region (Seshappa, 1953). Occasional heavy feeding was noticed in other months also. Amphipods were commonly met with in the stomachs in February–July, when they have been found to occur abundantly in this area, the common amphipod both in the stomach contents and in the environment being *Cheiriphotis megacheles*.

Good numbers of *Lucifer* and decapod larvæ were frequently observed in the stomach contents respectively, from November and January onwards till the end of April, when both of which are found abundantly in the plankton. Larval bivalves and cirripede larvæ which have been observed in the plankton throughout the year were noticed in the stomach contents also almost all through the period. The cladocerans formed an important food item during July–November and it is during the same period that they have been observed abundantly in the coastal waters off Calicut (George, *op. cit.*). Of the two cladocerans, *Evadne* and *Penilia*, the former was more common both in the stomach contents and in the plankton. Among miscellaneous food, brachyuran larvæ, chiefly zœa and megalopa stages, and the stomatopod, *Squilla*, were frequently observed in the stomachs during December-May when they were common in the plankton also.

Feeding intensity.—Table II shows the particulars about the feeding intensity of 20 species that were most common in the catches for all the 12 months. As already stated, the degree of feeding of each fish was noted as under one of the five categories: heavy, good, medium, poor or empty depending upon the state of distension of the stomach and the amount of feeding. The degree of feeding shown for each month is the highest degree noticed during that month. Taking these fishes as representative of the fish fauna of the area, a factor known as 'Feeding Index' is worked out after Kow (*op. cit.*), in order to assess the feeding intensity of the population as a whole. The feeding index for any one particular month is the ratio of the number of species whose feeding intensity was either heavy or good to the number of species examined during that month multiplied by 100. By this method it is possible to know "the level of the observed feeding intensity of the population during any one month".

It is seen from Table II and Fig. 6 that during the post-monsoon months of September–December, consistent with the greater availability of edible plankton and other food elements, there is a marked rise in the feeding intensity, the average feeding index for these 4 months being 67. It is during this period that maximum feeding is observed. In the subsequent months of January–May, the feeding intensity continues to be high during which period the occurrence of edible plankton is moderate while prawns, *Acetes* and such other food elements are in plenty. There is a lowering of the feeding intensity in the monsoon months of June–August when a decline in the occurrence of hitherto abundant food elements has been noticed. Another interesting feature observed from the examination of the gonadal condition of these fishes is that the period of high feeding intensity is more or less the same as the maturing period for many of them.

TABLE II

Feeding intensity and feeding index

Species	1952								1953			
	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Anchoviella tri	M	G	G	G	M	G	H	G	M	P	G
Anchoviella heteroloba	..	..	..	..	..	..	..	G	G	M	..	..
Dussumieria hasselti	..	..	..	E	..	..	..	P	P	P	P	..
Thrissocles malabaricus	M	G	P	P	G	..	G	G	H	.	M	M
Opisthopterus tardoore	G	G	G	M	P	P	M	H	G	G	G	G
Kowala coval ..	P	P	..	..	G	M	G	H	G	M	G	M
Sardinella albella ..	M	..	..	..	..	..	..	..	..	M	M	P
Sardinella longiceps	..	..	..	..	..	G	G	G	..	H	M	..
Sardinella fimbriata	M	M	..	..	..	G	H	G	M	M	G	M
Leiognathus insidiator	..	..	..	M	..	G	G	G	G	G	M	M
Leiognathus bindus	..	H	..	H	E	G	H	G	E	..	..	..
Leiognathus splendens	M	..	..	M	M	G	G	..	..	..	..	..

Ambassis gymnocephalus	..	..	..	G	..	H	G	H	G	G	M	G
Caranx kalla ..	M	P	P	G	M	G	E	G	M	M	G	G
Caranx djedaba ..	..	..	..	..	..	..	P	M	M	P	P	M
Scomberomorus guttatus	E	M	E	E	E	P	H	..	..	P	E	P
Pseudosciæna sina	H	M	M	P	..	..	..	M	G	G	H	H
Otolithes ruber ..	G	G	M	M	E	..	H	..	G	G	G	H
Lactarius lactarius	H	H	H	M	M	P	M	M	M	M	H	H
Johnius belengeri ..	G	G	M	..	M	..	H	G	..	..	..	..
Feeding index ..	42	50	33	31	27	58	75	75	60	38	44	50

H = heavy; G = good; M = medium; P = poor; E = empty.

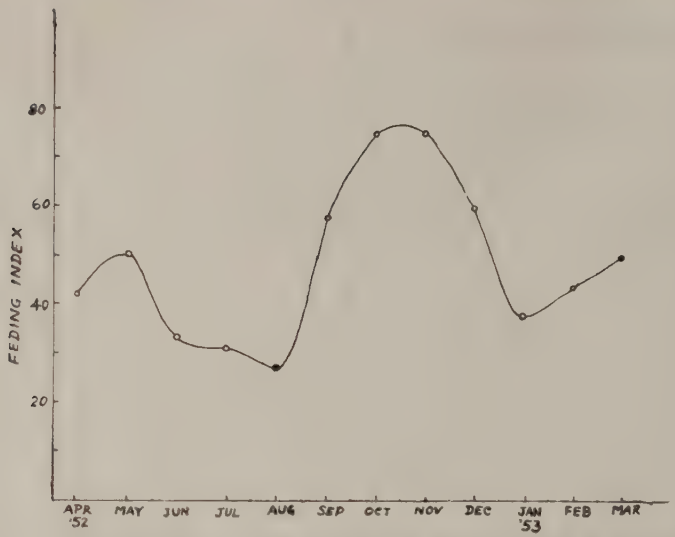

FIG. 6. Graph showing feeding index for 12 months from April 1952 to March 1953.

Food in relation to fisheries.—From the foregoing account interesting correlations between the nature of the fishery and the availability of particular types of food in the inshore waters can be made out. The peak of the fishery in this area, chiefly supported by plankton feeders like sardines and mackerels, is generally attained during the months of September–December, when the inshore waters are rich in plankton comprising of a large variety of phyto- and zooplanktonic elements. It is this season that George (*op. cit.*) has observed "to be a period of abundance of rich 'edible plankton' in the coastal waters". The recolonisation of the inshore sea bottom by a large variety of animals, an important member of which is *Prionospio pinnata*, takes place after the monsoon in September. Coinciding with this settlement of the bottom animals, the commencement of the fishery of the Malabar sole, *Cynoglossus semifasciatus* which is chiefly a bottom feeder and whose favourite food is *P. pinnata* also takes place in September (Seshappa and Bhimachar, 1955). The Malabar sole fishery continues to be good during the subsequent months of October–May in the region under discussion during which period the inshore sea bottom also sustains a rich bottom fauna including *P. pinnata*. Seshappa and Bhimachar (*op. cit.*) while referring to the movements of this fish into the inshore waters mention "that food factor plays an important role in the large-scale appearance of the fish" and "it seems particularly to favour polychætes usually

dominated along this coast by *P. pinnata* during the post-monsoon months".

In the months of January–May, the inshore fishery is rich characterised by the abundant occurrence of a large variety of fish like sciænids, engraulids, polynemids, etc., and this is to a large extent contributed by the presence of their favourite food, prawns, polychætes, amphipods, etc., in the inshore region at this period. Another food element which contributes to their rich fishery in the inshore waters is the small shrimp, *Acetes dispar*, whose plentiful occurrence is from March–May. In the monsoon months, there is a good fishery of the silver-bellies and white-baits whose favourite food is copepods, the large scale occurrence of which in the plankton at this period leads to infer that they contribute to a considerable extent to the rich fishery of the two fishes. Thus it is seen that the availability of particular types of food forms one of the factors governing the migratory movements of many of these fishes into the inshore waters.

Summary

This paper relates to the investigations carried out during 1948–53 on the food and feeding relationships of some of the common inshore fishes caught off Calicut on the Malabar coast. 7,328 specimens belonging to 47 species were examined for their stomach contents. A detailed qualitative and quantitative analysis under *points method*, of the food of 20 species and a general account of the food of the rest are given.

The inshore fishes possess diverse feeding habits. Some are plankton feeders while others are carnivorous or omnivorous. When some are surface-feeders others feed constantly at th bottom. Among plankton feeders, while fishes like *Sardinella longiceps* and *S. albella* have a special favour for phytoplankton, those like *Anchoviella* spp., *Dussumieria hasselti* and *Ambassis gymnocephalus* show a preference for zooplankton, and yet others, *viz.*, *Sardinella fimbriata* and *Leiognathus splendens* seem to feed both on phyto- and zooplankton without any discrimination. A good number of inshore fishes are found to be carnivores and excepting a few, which exhibit chiefly piscivorous and carcinivorous tendencies, the rest are cosmopolitan in their tastes, feeding on a large variety of organisms.

An account of the seasonal variation in the food of the fishes as a whole is given. A close correlation between their food and the food available in their environment could be made out. During the months of September–February the plankton of the coastal waters has been observed to be rich, characterised by the moderate abundance of phytoplankton and increased

occurrence of edible zooplankton elements and correspondingly these were noticed in abundance in the stomach contents of the plankton feeders like sardines and the mackerel. Large numbers of bottom animals recolonise in the inshore area in September after the monsoon break, and occur in abundance in this region then onwards till May. It is in this period that they were noticed in good numbers in the stomachs of those fishes which feed at the bottom. Prawns and *Acetes* have been found to occur abundantly in the inshore waters from January and March till May respectively and this is reflected in their abundant occurrence in the stomach contents also in the same period. During the monsoon months, large scale occurrence of copepods has been noticed in the coastal waters and these constituted the main food of silver-bellies and white-baits in this period.

The feeding intensity is noticed to be high during the post-monsoon and summer months while it is low in the monsoon months, the maximum feeding observed being in the months of September–December. The period of intense feeding is noticed to coincide with the maturing period for many of these fishes.

The relationship between the food and the fisheries is given. It is seen that the availability of particular types of food in the inshore area forms one of the factors governing the migratory movements of many of these fishes into the inshore waters.

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STUDIES ON THE PHYTOPLANKTON OF THE WEST COAST OF INDIA

Part III. Seasonal Variation of the Phytoplankters and Environmental Factors*

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Introduction

In this part of the studies, the seasonal distribution of the constituent elements of the phytoplankton as also the meteorological and hydrological conditions during the concerned period are presented based on data gathered over a period of five years by examination by the senior author of over 1,000 samples of plankton collection.

The methods employed have already been described in Parts I and II of this series (Subrahmanyan, 1959 *a*, *b*), and a list of species recorded on the west coast may be had from Subrahmanyan (1958 *b*). It may be pointed out here that the compilation given here of the various species is based on enumeration data only.

As an arrangement of all the species each month during a period of five years according to their order of abundance would be a formidable task, in the text of the paper, the picture has been abridged and the first twelve species alone which contribute to the bulk of the flora each month have been shown in their order of abundance taking into consideration all the respective months during the period of investigation; all the species, however, have been classified and incorporated in a table.

The several species of phytoplankton found each month, belonging to the different classes, were classified into four different categories. The species usually found to be dominant in most of the collections for the month, or through greater part of the month, are classed as "abundant species (*a*)". There is no constancy for the occurrence of species under the category "rare species (*r*) "; some of the species may not occur at all in certain years; the number of individuals present may be very few; and some of them may occur earlier or later to the expected period. However, it is believed, that as the observations have been continuous over the same area over a considerable number of years, the anomalies would have ironed themselves out, leaving an

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* Parts I and II appeared in the *Proc. Indian Acad. Sci.*, 1959, **50 B**, 113–87; 189–252.

overall reliable picture. The data presented here are such a picture of the records made during the respective months during the period May 1949 to April 1954.

While we have a fairly good picture of the seasonal distribution of phytoplankton for several regions abroad (Cupp, 1937; Dakin and Colefax, 1940; Johnstone *et al.*, 1924; Kokubo, 1932; Kokubo and Tamura, 1938; Kow, 1953; Lillick, 1937, 1938 and 1940; Margalef, 1951 *a*, *b*; 1957 *a*, *b*; Margalef and Duran, 1953; Margalef *et al.*, 1952, 1957; Ostenfeld, 1913; and Sheard, 1949)* the same cannot be said for the Indian waters, though there have been attempts at compilation of such accounts (Aiyar *et al.*, 1936; Chidambaram and Menon, 1945; George, 1953; Menon, 1931; Menon, 1945; Prasad, 1958). Be that as it may, most of the accounts are based on observations carried over a short period only; and the identification of the organisms has been, generally, up to the genus level only, in most of the instances. In the present account, identifications up to species level are given as otherwise it was felt that the wealth of species under many genera (*e.g.*, *Coscinodiscus* and *Chætoceros* of Bacillariophyceæ, and *Ceratium* and *Peridinium* of Dinophyceæ), the seasonal variation and cyclical occurrence of many of them will lead to confusion and leave a wrong picture of the real state in the waters if only the genera are listed. Further, an account with identification up to genera only will not be of much use to fishery biologists, particularly in their search for indicator organisms for a rational exploitation of the fishery resources. The value of detailed studies in this regard is well emphasised by Le Mare (quoted by Hardy, 1958, pp. 168–69). Zenkevitch (1958, p. 29) also rightly stresses the great significance of the seasonal trends in the qualitative and quantitative changes of plankton. He states that "If we possessed a general picture of the quantitative and qualitative distribution for a whole ocean, we would be able to apply, with much greater success, mathematical methods of calculation and prognosis of the biological processes taking place in the ocean-waters". An attempt has been made in the earlier accounts (Subrahmanyan, 1958 *a*; 1959 *a*, *b*) to contribute to an understanding of the total quantitative distribution of the microflora and its relationships; in this account an attempt is made towards elucidations of the seasonal variation in the nature and quantity (within broad limits) of the phytoplankton elements on the west coast of India. It is hoped that the data presented here will prove of great practical value in fisheries research. It is proposed to deal with the cyclical occurrence and ecological relationships of the most important species in another account.

* Only some select, geographically representative, references are given here.

Results

The relevant data collected during the investigation are presented below. It may be noted that under the biological aspect, the most abundant twelve species are given in their order of occurrence and in a separate table (Table I) all the organisms are listed and their relative quantitative abundance shown by indices.

Table I

Seasonal variations of the phytoplankton organisms†*

No.	Name of species	Months											
		J.	F.	M.	A.	My.	Jn.	Jy.	Ag.	S.	O.	N.	D.
	Bacillariophyceæ												
1	*Melosira sulcata* ..	o	o	o	r	r	r	r	r	r	—	—	r
2	*Stephanopyxis palmeriana*	—	o	o	r	r	o	r	—	r	—	—	—
3	*Sceletonema costatum* ..	c	a	r	r	a	a	a	a	r	a	c	a
4	*Coscinosira polychorda*	r	r	—	—	r	r	o	a	r	r	—	—
5	*Thalassiosira decipiens* ..	r	—	r	r	r	r	o	r	c	r	r	—
6	*T. hyalina* ..	r	r	r	r	r	r	r	c	c	r	r	r
7	*T. baltica* ..	r	r	—	—	r	r	r	r	r	r	r	r
8	*T. kryophila* ..	o	r	r	o	o	o	o	c	c	c	r	r
9	*T. subtilis* ..	o	c	r	r	a	a	—	r	—	r	—	—
10	*T. nana* ..	a	c	o	a	o	r	r	—	—	r	—	r
11	*Cyclotella meneghiniana*	—	—	—	—	—	—	—	—	—	r	—	—
12	*C. striata* ..	c	c	r	o	o	r	o	c	c	c	o	o
13	*Ethmodiscus gazellæ* ..	—	r	r	r	—	r	—	—	—	—	—	—
14	*Coscinodiscus excentricus*	o	c	o	o	c	o	c	c	c	c	r	r

* The forms are arranged in their taxonomic order. Explanations of abbreviations used:
a = abundant = > 1,000,000 cells per vertical net haul.
c = common = 10,000–1,000,000 cells per vertical net haul.
o = occasional = 1,000–10,000 cells per vertical net haul.
r = rare = < 1,000 cells per vertical haul. Usually very few, represented only by stray cells.
— = not recorded/absent.

† *See* Subrahmanyan (1946, 1958 *b*) for authority relating to the species.

TABLE I (*Contd.*)

No.	Name of species	Months											
		J.	F.	M.	A.	My.	Jn.	Jy.	Ag.	S.	O.	N.	D.
15	*C. excentricus* var. *fasciculata* ..	—	r	—	—	—	r	—	r	r	—	—	—
16	*C. lineatus* ..	r	r	r	r	r	r	a	c	o	r	r	r
17	*C. sub-lineatus* ..	—	—	—	—	—	—	—	—	—	—	r	—
18	*C. marginatus* ..	o	o	r	o	r	r	—	r	r	o	—	r
19	*C. radiatus* ..	o	o	o	r	r	o	r	r	—	r	r	r
20	*C. granii* ..	r	—	—	—	—	r	—	—	—	—	—	—
21	*C. granii* var. *aralensis* ..	—	r	—	—	—	—	—	—	—	—	—	—
22	*C. jonesianus* ..	—	—	r	—	—	—	—	—	—	—	—	—
23	*C. concinnus* ..	o	o	r	o	o	o	r	r	r	r	r	r
24	*C. thorii* ..	o	—	—	—	—	—	—	—	—	—	—	—
25	*C. schimperi* ..	r	—	—	—	—	—	—	—	—	—	—	—
26	*C. centralis* ..	—	o	r	r	r	—	r	r	r	r	—	—
27	*C. perforatus* ..	r	r	r	—	—	r	r	r	r	—	—	r
28	*C. perforatus* var. *pavillardi*	o	r	o	o	r	r	c	c	c	c	o	r
29	*C. apiculatus* ..	—	—	—	—	r	—	r	—	—	—	—	r
30	*C. asteromphalus* ..	o	o	c	o	o	o	c	o	c	c	o	o
31	*C. oculus-iridis* ..	o	o	o	c	c	o	o	c	c	c	o	o
32	*C. oculus-iridis* var. *borealis*	—	—	r	r	—	—	—	—	—	r	—	r
33	*C. gigas* var. *prætexta* ..	r	r	r	r	r	r	—	r	—	r	r	r
34	*C. janischii* ..	o	r	o	o	o	r	a	c	c	c	r	r
35	*Planktoniella sol* ..	o	o	o	c	c	c	c	o	r	r	r	r
36	*Actinoptychus undulatus*	r	r	r	—	r	o	a	a	c	c	o	r
37	*Asteromphalus flabellatus*	—	—	—	r	r	—	—	—	—	—	—	—
38	*A. wyvillei* ..	—	—	r	—	—	—	—	—	—	r	—	—
39	*Gossleriella tropica* ..	—	—	r	—	—	—	r	r	—	—	—	—
40	*Actinocyclus ehrenberghii*	r	—	—	r	—	r	—	—	—	r	r	r

TABLE I (*Contd.*)

No.	Name of species	Months											
		J.	F.	M.	A.	My.	Jn.	Jy.	Ag.	S.	O.	N.	D.
41	*Bacterosira fragilis* ..	r	—	—	r	r	r	—	r	—	—	—	r
42	*Corethron hystrix* ..	o	o	o	r	r	o	—	—	—	—	—	—
43	*C. inerme* ..	r	o	o	r	o	r	—	—	—	—	—	r
44	*Lauderia annulata* ..	a	c	a	c	a	a	a	c	o	o	c	o
45	*Schröderella delicatula* ..	a	a	a	a	a	a	r	r	r	r	r	o
46	*Leptocylindrus danicus* ..	a	c	o	o	a	a	c	c	c	o	o	r
47	*L. minimus* ..	c	o	r	r	r	r	c	r	r	r	o	r
48	*L. adriaticus* ..	r	o	r	o	r	o	r	r	r	r	r	—
49	*Guinardia flaccida* ..	c	c	o	a	c	o	o	c	c	o	r	r
50	*G. blavyana* ..	r	o	r	r	r	r	r	r	r	—	—	—
51	*G. victoriæ* ..	r	r	r	r	r	r	o	r	r	r	r	r
52	*Detonula confervacea* ..	—	o	r	r	r	r	r	r	—	—	—	—
53	*Rhizosolenia fragilissima*	r	—	r	o	r	r	r	—	r	r	—	r
54	*R. cylindrus* ..	r	—	r	r	—	—	r	—	—	—	—	—
55	*R. bergonii* ..	—	—	—	r	r	r	—	r	—	r	—	—
56	*R. stolterfothii* ..	c	c	o	a	a	a	c	o	o	o	r	r
57	*R. robusta* ..	c	c	c	o	o	c	o	c	o	r	o	o
58	*R. imbricata* ..	c	c	c	o	c	c	r	r	r	—	r	r
59	*R. styliformis* ..	r	r	r	r	r	r	r	—	—	r	—	—
60	*R. styliformis* var. *latissima* ..	o	o	o	r	r	r	r	—	r	r	r	r
61	*R. setigera* ..	c	o	o	r	c	c	c	r	a	o	o	r
62	*R. cochlea* ..	—	—	—	—	—	—	—	—	r	r	—	—
63	*R. calcaravis* ..	c	o	o	c	c	c	o	r	r	o	o	o
64	*R. crassispina* ..	c	c	o	c	c	c	c	c	o	r	r	r
65	*R. alata* ..	c	c	c	c	o	c	o	o	o	o	o	r
66	*R. alata* f. *gracillima* ..	o	o	a	—	r	r	c	c	c	c	o	r
67	*R. alata* f. *indica* ..	r	r	o	r	c	o	r	r	r	—	—	r

TABLE I (*Contd.*)

No.	Name of species	Months											
		J.	F.	M.	A.	My.	Jn.	Jy.	Ag.	S.	O.	N.	D.
68	*R. castracanei* ..	—	—	—	—	r	—	—	—	—	—	—	—
69	*R. castracanei* var. *rhomboidea*	r	r	o	c	r	—	—	—	—	—	—	—
70	*R. simplex* ..	—	—	—	—	r	—	—	—	—	—	—	—
71	*Bacteriastrum delicatulum*	a	c	o	o	c	c	c	r	—	—	r	r
72	*B. hyalinum* ..	—	r	r	—	—	—	r	r	r	—	—	—
73	*B. hyalinum* var. *princeps*	a	c	c	a	c	c	c	c	c	c	r	c
74	*B. varians* ..	o	o	r	r	r	r	—	r	r	r	r	r
75	*B. mediterraneum* ..	—	—	o	r	—	—	—	—	—	—	—	r
76	*B. elegans* ..	—	r	r	r	—	r	—	—	—	—	—	—
77	*B. comosum* ..	o	o	o	o	r	r	—	—	—	r	—	r
78	*B. simplex* ..	o	o	r	o	a	o	r	—	—	r	r	c
79	*B. solitaria* ..	—	—	—	—	r	—	—	—	—	—	—	—
80	*Chætoceros atlanticum* ..	r	r	—	—	r	—	—	—	—	—	—	—
81	*C. atlanticum* var. *neopolitana* ..	o	r	—	—	r	r	—	—	—	—	—	—
82	*C. eibenii* ..	—	—	—	r	r	—	—	—	r	r	—	..
83	*C. coarctatus* ..	c	o	o	o	r	o	r	r	r	r	c	o
84	*C. danicus* ..	o	r	o	o	r	o	o	r	c	r	r	o
85	*C. borealis* ..	o	o	r	r	r	o	a	r	r	—	c	c
86	*C. denticulatum* ..	c	o	o	r	o	o	c	r	r	r	r	o
87	*C. peruvianus* ..	c	c	o	o	c	o	o	r	c	r	c	r
88	*C. peruvianus* var. *robusta* ..	r	—	o	r	r	r	—	—	—	r	—	r
89	*C. decipiens* ..	o	o	r	r	c	o	o	c	a	c	r	c
90	*C. mitra* ..	r	—	r	—	r	r	r	c	—	r	r	r
91	*C. lorenzianus* ..	a	a	a	a	a	a	a	a	a	a	a	a
92	*C. lauderi* ..	c	c	c	c	c	c	o	r	r	c	r	c
93	*C. compressus* ..	a	c	a	a	o	c	a	c	a	a	a	a

TABLE 1 (*Contd.*)

No.	Name of species	Months											
		J.	F.	M.	A.	My.	Jn.	Jy.	Ag.	S.	O.	N.	D.
94	*C. didymus*	o	r	o	r	r	o	o	o	c	a	o	o
95	*C. didymus* var. *protuberans*	r	—	—	—	—	—	—	—	—	r	—	—
96	*C. didymus* var. *heterosetoides*	—	r	—	r	r	r	—	r	—	—	r	r
97	*C. contortum*	a	a	a	o	a	r	o	r	—	—	r	a
98	*C. van heurckii*	—	r	o	—	r	—	r	—	—	—	—	r
99	*C. affinis*	a	a	r	o	c	a	a	c	c	a	a	c
100	*C. affinis* var. *circinalis*	—	—	—	—	—	—	r	—	—	—	—	—
101	*C. paradoxum*	—	—	—	—	r	—	—	—	—	—	—	—
102	*C. lasciniosus*	c	c	o	a	r	o	c	o	o	a	c	a
103	*C. pelagicus*	r	o	r	a	a	a	r	r	—	a	r	r
104	*C. brevis*	c	c	o	r	c	c	a	a	r	r	r	r
105	*C. seriacanthus*	—	—	—	—	—	—	—	—	—	—	—	c
106	*C. holsaticus*	r	r	r	r	—	r	r	r	—	—	—	—
107	*C. diversus*	r	o	o	r	r	r	r	r	r	—	o	c
108	*C. lævis*	—	—	r	r	r	—	—	—	—	—	—	—
109	*C. ralfsii*	r	r	o	r	r	o	r	o	r	—	r	r
110	*C. messanensis*	—	r	r	r	r	—	—	—	—	—	—	—
111	*C. wighami*	r	r	r	—	—	—	r	—	—	—	—	r
112	*C. filiformis*	—	r	—	r	r	r	—	—	r	—	—	—
113	*C. curvisetus*	a	a	a	a	a	a	a	a	a	a	a	a
114	*C. filiferum*	r	—	—	—	—	—	—	—	—	—	—	c
115	*C. socialis*	a	a	r	a	c	a	c	r	a	a	c	c
116	*C. myriapodus*	—	—	—	—	—	—	—	—	—	c	—	—
117	*Eucampia zoodiacus*	r	o	r	r	r	o	r	r	r	—	r	r
118	*E. cornuta*	r	o	o	o	o	o	r	r	r	r	r	r
119	*Climacodium frauenfeldianum*	r	r	r	r	r	r	—	—	—	—	—	—

TABLE 1 (*Contd.*)

No.	Name of species	Months											
		J.	F.	M.	A.	My.	Jn.	Jy.	Ag.	S.	O.	N.	D.
120	*Streptotheca indica* ..	c	c	o	o	o	c	o	r	r	r	r	o
121	*Bellerochea malleus* ..	r	r	r	c	a	—	—	—	r	—	—	r
122	*B. indica* ..	—	—	—	—	—	—	—	—	—	—	—	r
123	*Ditylum sol* ..	o	o	o	o	c	a	o	r	r	r	r	o
124	*Triceratium favus* ..	r	r	r	r	r	r	r	r	—	r	r	r
125	*T. dubium* ..	—	—	—	—	—	—	—	r	—	—	—	—
126	*Biddulphia sinensis* ..	c	c	c	c	c	c	c	r	r	o	r	r
127	*B. mobiliensis* ..	o	o	o	o	c	a	a	c	o	o	o	o
128	*B. heteroceros* ..	c	c	c	c	o	c	c	o	o	o	o	o
129	*B. japonica* ..	—	—	—	r	r	—	—	r	—	r	—	—
130	*B. rhombus* ..	—	—	—	—	r	r	—	—	r	r	r	—
131	*B. aurita* ..	r	r	—	—	r	r	r	—	—	—	r	r
132	*Cerataulina bergoni* ..	o	o	r	o	r	o	r	r	r	r	—	r
133	*Hemiaulus hauckii* ..	—	r	—	r	r	—	r	—	—	—	—	—
134	*H. sinensis* ..	r	o	o	r	o	c	—	—	—	—	r	r
135	*H. membranaceus* ..	r	r	o	o	o	r	—	r	—	r	o	o
136	*Hemidiscus hardmannianus* ..	r	r	c	r	o	r	r	r	—	r	c	r
137	*Fragilaria oceanica* ..	a	a	a	c	a	a	a	a	a	a	a	a
138	*Thallassionema nitzschioides*	o	o	r	r	c	a	a	o	r	r	r	r
139	*Thallasiothrix longissima*	c	o	o	o	c	c	c	o	c	c	o	—
140	*T. frauenfeldii* ..	o	c	a	o	c	a	a	a	o	c	c	o
141	*Asterionella japonica* ..	a	a	r	a	c	a	a	a	c	c	c	c
142	*Mastogloia exilis* ..	—	—	—	—	—	—	—	r	—	—	—	—
143	*Pleurosigma elongatum* ..	o	c	o	c	o	r	c	c	o	o	r	r
144	*P. normani* ..	o	—	c	c	o	r	r	r	r	r	—	r
145	*P. angulatum* ..	o	c	r	r	r	r	r	r	o	r	r	r

TABLE 1 (*Contd.*)

No.	Name of species	Months											
		J.	F.	M.	A.	My.	Jn.	Jy.	Ag.	S.	O.	N.	D.
146	*P. æstuarii* ..	r	r	r	r	—	r	r	r	—	r	—	—
147	*P. directum* ..	—	—	—	—	—	—	—	—	r	—	—	—
148	*P. directum* var. *membranacea*	—	—	r	—	—	r	r	r	r	c	r	—
149	*Caloneis madraspatensis*	—	r	r	—	—	—	—	—	—	—	—	—
150	*Diploneis robustus* ..	—	—	—	—	—	—	—	—	—	r	—	—
151	*Navicula membranacea*	r	r	o	r	r	r	—	r	—	r	r	r
152	*N. alpina* ..	—	r	—	—	—	—	—	—	—	—	—	—
153	*Trachyneis aspera* var. *genuina* ..	r	r	r	r	r	r	—	—	—	—	r	r
154	*Amphiprora gigantea* var. *sulcata*	r	—	r	r	—	—	r	—	r	—	—	r
155	*Amphora pusio* ..	—	—	—	—	—	—	—	—	r	—	—	—
156	*Bacillaria paradoxa* ..	r	—	r	r	r	r	—	—	—	—	—	—
157	*Nitzchia pelagica* ..	r	r	—	r	—	r	r	r	r	r	r	c
158	*N. panduriformis* var. *continua*	r	—	—	—	—	—	—	r	—	—	—	—
159	*N. sigma* var. *indica* ..	c	c	c	c	c	o	c	c	c	o	c	o
160	*N. closterium* ..	r	o	o	r	—	r	r	r	o	r	o	r
161	*N. longissima* ..	—	—	—	—	—	r	—	—	—	r	r	r
162	*N. seriata* ..	a	a	a	a	a	a	a	c	c	a	c	c
163	*Surirella fluminensis* ..	r	r	r	r	r	—	—	—	—	—	—	—
164	*Campylodiscus iyengarii*	—	—	—	r	—	—	—	—	—	—	—	—
	DINOPHYCEÆ												
165	*Exuviella compressa* ..	—	—	—	—	—	—	—	—	—	r	—	r
166	*Prorocentrum micans* ..	—	—	—	r	—	r	r	r	r	c	c	r
167	*Phalacroma rotundatus*	—	—	—	—	—	—	—	—	—	r	—	r
168	*P. dolychopterigium* ..	—	—	—	—	—	—	—	—	—	r	r	r

TABLE I (*Contd.*)

No.	Name of species	Months											
		J.	F.	M.	A.	My.	Jn.	Jy.	Ag.	S.	O.	N.	D.
169	*Dinophysis ovum* ..	—	—	—	—	—	r	r	—	—	r	r	—
160	*D. acuminata* ..	—	—	—	—	—	—	r	r	r	r	r	—
171	*D. caudata* ..	o	o	c	c	c	a	c	c	c	o	o	c
172	*D. caudata* f. *acutiformis*	r	—	—	o	r	—	r	—	r	r	o	r
173	*D. miles* ..	—	—	—	—	—	—	—	r	—	—	—	—
174	*D. miles* f. *indica* ..	r	o	o	o	o	r	r	—	—	o	o	c
175	*Amphisolenia elongata* ..	—	—	—	r	—	—	—	—	—	—	—	—
176	*A. bidentata* ..	—	—	—	—	r	—	—	—	—	—	—	—
177	*Ornithocercus magnificus*	o	r	—	r	c	c	r	r	r	c	c	c
178	*Gymnodinium gelbum* ..	—	—	—	—	—	—	r	r	r	—	—	—
179	*G. marinum* ..	—	—	—	—	r	r	—	r	r	—	r	r
180	*G. mirabile* ..	r	—	—	—	r	r	—	r	r	—	r	—
181	*G. splendens* ..	—	—	—	r	—	r	r	r	r	r	r	r
182	*G. uberrimum* ..	r	—	—	r	—	—	r	r	r	—	r	—
183	*G. variabile* ..	—	—	—	—	—	—	—	r	—	r	r	—
184	*Massartia glauca* ..	—	—	—	—	—	—	r	—	—	—	—	—
185	*Gyrodinium lingulifera* ..	—	—	—	—	—	—	—	—	—	—	r	—
186	*G. obtusum* ..	—	—	—	r	—	—	—	—	—	—	—	—
187	*G. pingue* ..	—	—	—	r	—	—	—	—	—	—	—	—
188	*G. spirale* ..	—	—	—	—	—	—	r	r	—	—	r	—
189	*Polykrikos schwarzi* ..	—	—	—	—	—	—	—	—	—	—	r	—
190	*Noctiluca miliaris* ..	o	r	o	a	c	a	c	c	c	c	c	c
191	*Paulsenella chætoceratis*	—	—	r	—	—	—	—	—	—	—	—	—
192	*Pyrophacus horologicum*	r	r	r	o	o	r	c	o	r	r	o	o
193	*P. horologium* var. *steinii*	r	—	r	r	r	r	r	r	r	r	r	r
194	*Glenodinium lenticula* ..	—	—	—	r	—	—	—	—	—	—	—	—
195	*G. lenticula* f. *minor* ..	—	—	—	—	—	—	r	r	—	r	—	—
196	*G. lenticula* f. *asymmetrica* ..	c	a	o	c	c	a	o	o	r	o	c	o

TABLE I (*Contd.*)

No.	Name of species	Months											
		J.	F.	M.	A.	My.	Jn.	Jy.	Ag.	S.	O.	N.	D.
197	*G. pilula* ..	—	—	—	r	—	r	—	r	r	r	—	—
198	*G. trochoideum* ..	—	—	—	r	r	r	o	r	—	r	—	—
199	*Peridinium bulla* ..	r	—	r	r	r	r	r	r	r	r	—	r
200	*P. hylanium* ..	—	—	—	—	—	r	—	r	r	—	r	r
201	*P. minutum* ..	—	—	r	r	r	r	r	—	—	—	r	—
202	*P. thorianum* ..	r	—	—	—	—	r	—	r	—	—	—	r
203	*P. excentricum* ..	r	—	r	r	r	r	r	—	—	—	r	o
204	*P. globulus* ..	r	—	r	r	r	r	r	r	r	r	r	r
205	*P. globulus* var. *quarnerense*	r	r	r	r	r	r	r	r	r	—	r	r
206	*P. globulus* var. *ovatum*	r	r	—	—	—	r	—	r	r	r	r	—
207	*P. granii* ..	r	r	r	r	o	o	r	o	—	r	r	r
208	*P. steinii* ..	r	—	—	—	—	—	—	—	—	—	r	r
209	*P. steinii* var. *mediterraneum* ..	r	o	r	r	r	c	—	—	r	r	r	c
210	*P. breve* ..	—	—	—	—	—	—	—	—	—	—	r	—
211	*P. pedunculatum* ..	—	—	r	—	—	—	—	—	—	—	—	—
212	*P. brochii* ..	r	r	r	r	—	a	r	r	r	r	—	r
213	*P. brochii* var. *inflatum*	—	—	—	—	r	r	r	r	r	r	r	—
214	*P. crassipes* ..	r	—	r	r	—	o	o	r	r	r	r	—
215	*P. divergens* ..	r	r	—	r	r	r	r	r	r	—	r	r
216	*P. conicoides* ..	r	—	r	r	r	r	r	r	r	r	r	—
217	*P. conicum* ..	r	o	o	r	r	r	o	r	r	r	r	r
218	*P. humile* ..	—	—	—	—	—	—	r	—	—	—	r	—
219	*P. leonis* ..	—	—	r	—	—	r	r	r	r	r	r	—
220	*P. leonis* f. *matzenaueri* ..	r	r	r	r	r	r	r	r	r	c	r	r
221	*P. pentagonum* ..	r	r	—	r	r	r	r	r	r	r	—	—
222	*P. subinerme* ..	—	—	—	r	r	—	—	—	—	—	—	r
223	*P. claudicans* ..	—	—	—	—	r	—	r	—	r	—	r	r

TABLE I (*Contd.*)

No.	Name of species	Months											
		J.	F.	M.	A.	My.	Jn.	Jy.	Ag.	S.	O.	N.	D.
224	*P. depressum* ..	a	c	o	o	c	c	c	c	r	o	c	c
225	*P. grande* ..	r	r	r	—	—	c	r	r	r	r	r	—
226	*P. elegans* ..	—	—	—	—	—	—	—	—	—	—	—	r
227	*P. murrayi* ..	r	—	r	r	—	r	—	—	—	r	r	r
228	*P. oceanicum* ..	r	o	r	r	r	o	o	r	r	r	o	c
229	*P. venustrum* ..	—	—	—	—	—	r	r	—	r	r	r	—
230	*P. sinaicum* ..	r	o	r	r	r	o	o	r	r	r	r	r
231	*Gonyaulax diegœnsis* ..	r	—	—	r	r	r	—	—	—	r	r	r
232	*G. scrippsæ* ..	—	—	—	r	—	r	—	r	r	r	r	r
233	*Ceratium candelabrum* ..	—	—	—	—	—	—	—	—	—	—	r	—
234	*C. candelabrum* f. *curvatulum* ..	—	—	—	—	—	—	—	—	—	—	—	r
235	*C. furca* ..	r	—	—	—	—	—	r	r	—	—	—	—
236	*C. furca* f. *eugrammum* ..	o	o	r	o	o	o	r	r	r	r	o	c
237	*C. lineatum* ..	r	—	—	—	—	—	—	—	—	r	—	—
238	*C. setaceum* ..	r	r	r	—	—	r	—	r	—	—	r	r
239	*C. inflatum* ..	o	r	r	r	r	r	o	r	—	—	r	r
240	*C. longirostrum* ..	—	—	—	—	—	—	r	—	—	—	r	r
241	*C. fuscus* ..	c	o	o	c	o	c	c	c	c	c	c	c
242	*C. fuscus* var. *seta* ..	—	—	—	—	—	r	—	—	—	—	—	—
243	*C. dens* ..	o	o	r	r	r	r	r	r	r	—	r	r
244	*C. tripos* ..	a	c	a	c	c	c	c	c	r	o	c	c
245	*C. tripos* var. *atlanticum*	—	—	—	—	r	—	—	—	—	—	—	—
246	*C. tripos* f. *ponticum* ..	r	—	—	—	—	—	—	—	—	—	—	r
247	*C. tripos* f. *subsalsum* ..	—	—	—	—	—	r	—	—	—	—	—	—
248	*C. pulchellum* f. *semipulchellum*	r	—	—	r	r	—	r	—	r	r	r	r
249	*C. porrectum* ..	—	—	—	—	—	r	—	—	—	—	—	—

TABLE I (*Contd.*)

No.	Name of species	Months											
		J.	F.	M.	A.	My.	Jn.	Jy.	Ag.	S.	O.	N.	D.
250	*C. humile* ..	—	—	—	—	—	r	r	—	—	—	—	—
251	*C. breve* ..	r	r	r	r	r	r	r	r	r	r	r	c
252	*C. bucephalum* ..	—	—	—	—	—	r	—	—	—	—	—	r
253	*C. karstenii* f. *robustum*	—	—	—	—	r	—	r	—	—	—	—	r
254	*C. gibberum* ..	—	—	—	—	r	r	r	r	—	r	r	r
255	*C. schmidtii* ..	—	—	—	—	—	—	r	—	—	—	—	—
256	*C. longipes* ..	r	r	r	r	r	r	r	r	r	r	r	r
257	*C. longipes* f. *balticum*	r	—	—	—	—	r	r	—	—	—	—	—
258	*C. horridum* ..	—	—	—	r	r	r	r	r	r	r	r	—
259	*C. horridum* var. *sumatranum*	—	—	—	r	r	r	r	r	—	—	—	r
260	*C. buceros* ..	r	—	r	o	r	r	r	r	r	—	r	—
261	*C. vultur* ..	—	—	—	—	—	r	—	—	—	—	—	—
262	*C. cultur* var. *sumatranum*	—	r	—	—	—	r	r	—	r	—	r	—
263	*C. massiliense* ..	r	—	r	—	—	r	r	r	—	—	r	r
264	*C. massiliense* f. *macroceroides* ..	o	r	o	r	c	r	o	o	c	r	r	c
265	*C. massiliense* f. *armatum*	—	—	—	—	—	r	—	—	—	—	—	—
266	*C. carriense* ..	r	—	—	—	—	—	r	—	—	—	—	r
267	*C. carriense* f. *volans* ..	—	r	r	—	r	r	r	r	—	—	r	—
268	*C. macroceros* ..	o	o	c	c	o	r	c	c	o	c	c	o
269	*C. trichoceros* ..	o	r	r	r	r	r	r	—	—	—	r	r
270	*Cladopyxis caryophyllum*	r	—	—	—	—	—	—	—	—	—	r	r
271	*Podolampas palmipes* ..	—	—	—	—	—	—	—	—	r	—	r	—
272	*Pyrocystis pseudonoctiluca*	—	—	—	—	r	—	—	—	—	—	—	—
273	*P.* (*dissodinium*) *fusiformis*	—	—	—	r	r	r	—	—	—	—	—	—
274	*P.* (*Dissodinium*) *fusiformis* f. *biconica* ..	—	—	r	—	—	—	—	—	—	—	—	—

No.	Name of species	Months											
		J.	F.	M.	A.	My.	Jn.	Jy.	Ag.	S.	O.	N.	D.
275	*P. lunula*	—	—	—	—	—	—	—	—	—	—	—	r
	CHLOROMONADINEÆ												
276	*Hornellia marina*	—	—	—	r	—	—	—	r	o–c	r	r	r
	MYXOPHYCEÆ												
277	*Lyngbya æstuarii*	—	—	r	r	—	—	—	—	—	—	—	—
278	*Trichodesmium erythræum*	c	a	c–a	c–a	o	c	c	r	—	r	r	r
279	*T. thiebautii*	o	r	r	—	r	r	—	—	—	—	r	r
280	*T. contortum*	o	a	o	—	—	—	r	—	—	—	r	—
281	*Katagnymene spiralis*	—	—	—	—	r	—	—	—	—	—	—	—
282	*K. pelagica*	—	—	—	—	—	—	r	—	—	—	—	—
283	*Richelia intracellularis*	r	—	r	r	r	—	—	—	—	—	—	—
	EUGLENINEÆ												
284	*Protoeuglena noctilucæ*	—	—	o–r	o	o	r	—	—	—	—	—	r
	SILICOFLAGELLATÆ												
285	*Mesocena polymorpha* var. *quadrangula*	—	—	—	—	—	—	—	r	—	—	r	—
286	*M. polymorpha* var. *bioctonaria*	—	—	—	—	—	r	—	—	—	—	—	—
287	*Dictyocha staurodon*	—	—	—	—	—	—	r	—	—	—	—	—
288	*D. fibula*	—	—	—	—	—	—	—	—	—	—	—	r
289	*D. fibula* var. *longispina*	—	r	—	—	—	—	—	—	—	—	—	—
290	*Distephanus speculum*	—	—	—	—	—	—	—	—	—	—	r	—
	COCCOLITHINFÆ												
291	*Rhabdosphæra longistylis*	—	—	—	—	—	—	—	r	—	—	—	—

January—

1. *Rainfall.*—The driest month of the year. Varies from 0–5·1 mm. Mean, 1·6 mm.

2. *Humidity of the air.*—71–76%. Mean, 73%.

3. *Condition of the sea.*—Calm sea, water very clear.

4. *Wind.*—Mainly from north, north-west. Sometimes strong in the afternoons. Velocity 6–6·8 m.p.h.; mean, 6·4 m.p.h.

5. *Current*[1].—From north to south, steady.

6. *Hydrological data*:

(*a*) *Temperature*: (i) *Air.*—27·0–27·3° C. Mean, 27·15° C.

(ii) *Sea-water.*—27·5–28·7° C. Mean, 28·1° C.

(*b*) *Salinity of sea-water*: 31·68–34·45‰ at the surface and 31·95–34·75‰ at the bottom. Mean for water column 33·54‰.

(*c*) *Oxygen content*: 4·05–5·14 ml. per litre (saturation, 87–109·50%); Mean 4·48 ml. per litre (95·75% saturation).

(*d*) *Phosphate-Phosphorus*[2]: 0·150–0·656 *µg. at/L.* at the surface and 0·184–0·771 *µg. at/L.* at the bottom. Mean 0·440 *µg. at/L.*

(*e*) *Nitrate-Nitrogen*: 2·70–12·25 *µg. at/L.* at the surface and 2·37–2·90 *µg. at/L.* at the bottom. Mean, 4·434 *µg. at/L.*

(*f*) *Silicate-Silicon*: 6·30–22·21 *µg. at/L.* at the surface and 8·75–33·12 *µg. at/L.* at the bottom. Mean, 12·678 *µg. at/L.*

7. *Volume of plankton*[3].—The plankton crop is generally poor during the month and remains at a low level. In some years, occasionally, an increase in volume may be noticed towards the end of the month.

8. *Quantity of phytoplankton in plant pigment units* (*Harvey units*)[4].—Generally poor, an increase may be noticed towards the end of the month. Varies from 640–4,270 units per vertical net haul. Mean, 2,472 units.

9. *Dominant organisms.*—Zooplankters dominate the plankton. Phytoplankton is scarce, but may show an increase towards the end of the month.

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[1] At the actual station of sampling.

[2] Values corrected for salt error.

[3] A relative idea of the standing crop in terms of volume (based on horizontal hauls) may be had from George (1953).

[4] Hereafter will be referred to as *Pigment units.*

10. *General nature of phytoplankton.*—Diatoms and Dinophyceæ common. Blue-green algæ may also occasionally be seen, sometimes dominant.

11. *Dominant phytoplankters*[5].—*Chætoceros socialis, Asterionella japonica, Chætoceros contortum, Thalassiosira nana, Ceratium tripos, Chætoceros lorenzianus C. compressus, Fragilaria oceanica, Chætoceros curvisetus, Nitzschia seriata, Schroederella delicatula, Peridinium depressum.*

February—

1. *Rainfall.*—0·0–43·2 mm. Mean, 13·9 mm.

2. *Humidity.*—Condition similar to the previous month. 71–76%. Mean 74%.

3. *Condition of the sea.*—Calm, water clear.

4. *Wind.*—Mainly from the north, north-west. Strong at times in the afternoons. Force varies from 6·9–8·7 m.p.h. Mean, 7·6 m.p.h.

5. *Current.*—From north to south, steady.

6. *Hydrological data.*—

(*a*) *Temperature*: (i) *Air.*—27·4–28·8° C. Mean, 28·1° C.
(ii) *Sea-water.*—28·1–29·2° C. Mean, 28·6° C.

(*b*) *Salinity.*—31·88–34·35‰ at the surface and from 32·76–34·57‰ at the bottom. Mean, 33·88‰.

(*c*) *Oxygen content.*—3·57–5·17 ml./L. (saturation, 77·50–110·23%). Mean, 4·62 ml./L. (saturation, 98·96%).

(*d*) *Phosphate-Phosphorus.*—0·299–0·759 $\mu g.\ at/L.$ at the surface and 0·207–0·863 $\mu g.\ at/L.$ at the bottom. Mean, 0·532 $\mu g.\ at/L.$

(*e*) *Nitrate-Nitrogen*: 2·14–13·67 $\mu g.\ at/L.$ at the surface and 3·38–5·40 $\mu g.\ at/L.$ at the bottom. Mean, 5·727 $\mu g.\ at/L.$

(*f*) *Silicate-Silicon*: 5·18–19·16 $\mu g.\ at/L.$ at the surface and 6·67–22·20 $\mu g.\ at/L.$ at the bottom. Mean, 10·476 $\mu g.\ at/L.$

7. *Volume of plankton.*—The volume shows a marked increase to a very high level in certain years owing to the secondary phytoplankton bloom. Otherwise volume is rather low.

8. *Pigment units.*—860–3,310 units per haul. Mean, 2,026 units. Pigment values not proportionate to bulk of phytoplankton as that will depend on the nature of the flora (Subrahmanyan, 1959 *a*).

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[5] The dominant species for all months are arranged in the order of their dominance. In some years the order may be different owing to life-history factors leading to a cyclical mode in their occurrence.

9. *Dominant organism.*—Generally zooplankton; but on some occasions phytoplankton dominates as a result of a bloom.

10. *General nature of phytoplankton.*—Blue-green algæ often very common, at times in swarms forming a surface scum. Diatoms and Dinophyceæ, as usual common.

1. *Dominant phytoplankters.—Trichodesmium erythræum, Nitzschia seriata, Chætoceros curvisetus, Schroederella delicatula, Chætoceros socialis, C. lorenzianus, C. contortum, Sceletonema costatum, Chætoceros affinis, Fragilaria oceanica, Glenodinium lenticula,* f. *asymmetrica, Asterionella japonica.*

March—

1. *Rainfall.*—0·0–20·4 mm. Mean, 7·4 mm.

2. *Humidity.*—68–74%. Mean, 72%.

3. *Condition of the sea.*—Calm, water clear.

4. *Wind.*—Mainly from the north, Strong at times in the afternoons. Velocity varies from 7·6–8·9 m.p.h.; mean, 8·2 m.p.h.

5. *Current.*—From north to south, steady.

6. *Hydrological data.—*

(*a*) *Temperature*: (i) *Air.*—On the increase. 28·8–29·4° C. Mean, 29·1° C.

(ii) *Sea-water.*—Increase compared with previous month. 29·2–30·0 ° C. Mean, 29·5° C.

(*b*) *Salinity*: Upward trend. 34·49–35·54‰ at the surface and 34·47–35·45‰ at the bottom. Mean, 34·65‰.

(*c*) *Oxygen content*: Values show downward trend. 3·68–4·56 ml./L. (saturation, 80·10–100·3(%). Mean, 3·88 ml./L. (saturation, 89·82%).

(*d*) *Phosphate-Phosphorus.*—Values show an increase. 0·22–0·933 *µg. at/L.* at the surface and 0·345–1·15 *µg. at/L.* at the bottom. Mean, 0·551 *µg. at/L.*

(*e*) *Nitrate-Nitrogen*: Values decrease. 0·89–11·61 *µg. at/L.* at the surface and 0·43–1·85 *µg. at/L.* at the bottom. Mean, 3·521 *µg. at/L.*

(*f*) *Silicate-Silicon.*—Downward trend. 5·60–12·98 *µg. at/L.* at the surface and 7·17–15·09 *µg. at/L.* at the bottom. Mean, 10·81 *µg. at/L.*

7. *Volume of plankton.*—Fluctuates. Generally low towards the end of the month.

8. *Pigment units.*—Fluctuates very widely. Vary from 380–6,860 units per net haul. Mean, 3,898 units.

9. *Dominant organisms.*—Most of the time zooplankton. Occasionally a bloom of phytoplankton occurs.

10. *General nature of phytoplankton.*—Diatoms and bluegreen algæ most-common. Dinophyceæ also occur noticeably.

11. *Dominant phytoplankters.—Chætoceros curvisetus, C. compressus, Nitzschia seriata, Chætoceros lorenzianus, Fragilaria oceanica, Thalassiothrix frauenfeldii, Chætoceros contortum, Lauderia annulata, Schræderella delicatula, Rhizosolenia alata* f. *gracillima, Trichodesmium erythraeum, Ceratium tripos.*

April—

1. *Rainfall.*—Pre-monsoon showers occur. 26·0–175·3 mm. Mean, 122·7 mm.

2. *Humidity.*—74–76%. Mean, 75%.

3. *Condition of the sea.*—Calm, water clear. On some days breakers present.

4. *Wind.*—Mainly from the north. Velocity varies from 8·2–9·5 m.p.h. Mean, 8·7 m.p.h.

5. *Current.*—North to south, steady.

6. *Hydrological data.—*

(*a*) *Temperature*: (i) *Air.*—Marked fluctuations in this month. Sudden fall at times owing to showers. 26·1–29·9° C. Mean, 28·6° C.

(ii) *Sea-water.*—Increase noticed. 29·2–30·5° C. Mean, 30·0° C.

(*b*) *Salinity.*—33·87–35·89‰ at the surface and 33·97–36·08‰ at the bottom. Mean, 34·92‰.

(*c*) *Oxygen content*: Values show an upward trend. 3·62–6·07 ml./L. (saturation, 80·00–131·90%). Mean, 4·53 ml./L. (saturation, 100·11%).

(*d*) *Phosphate-Phosphorus*: 0·322–0·886 *µg. at/L.* at the surface and 0·322–0·920 *µg. at/L.* at the bottom. Mean, 0·575 *µg. at/L.*

(*e*) *Nitrate-Nitrogen*: 1·36–6·70 *µg. at/L.* at the surface and 0·77–1·75 *µg. at/L.* at the bottom. Mean, 3·194 *µg. at/L.*

(*f*) *Silicate-Silicon*: 7·21–12·50 *µg. at/L.* at the surface and 9·17–14·71. *µg. at/L.* at the bottom. Mean 10·313 *µg. at/L,*

7. *Volume of plankton.*—Not much fluctuation.

8. *Pigment units.*—490–3,400 units per net haul. Mean, 1,280 units.

9. *Dominant organisms.*—Zooplankters predominantly.

10. *General nature of phytoplankton.*—Diatoms and Dinophyceans form the dominant phytoplankters. Blue-green algæ also seen.

11. *Dominant phytoplankters.—Chætoceros lorenzianus, Guinardia flaccida, Chætoceros socialis, C. curvisetus, Nitzschia seriata, Rhizosolenia stolterfothii, Thalassiosira nana, Asterionella japonica, Chætoceros lasciniosus, C. compressus, C. pelagicus, Trichodesmium erythræum.*

May—

1. *Rainfall.*—South-west monsoon rains begin. Heavy during the second half of the month. 28·0–575·6 mm. Mean, 331·5 mm.

2. *Humidity.*—Increases. 76–81%. Mean, 79%.

3. *Condition of the sea.*—Occasionally rough. Water somewhat turbid.

4. *Wind.*—From north or north-west. Velocity varies from 7·7–9·9 m.p.h.; Mean, 8·6 m.p.h.

5. *Current.*—North to south.

6. *Hydrological data.—*

(*a*) *Temperature*: (*i*) *Air.*—29·6–30·3° C. Mean, 29·95° C.

(ii) *Sea-water.*—28·4–29·7° C. Mean, 29·2 C.

(*b*) *Salinity.*—34·74–35·65‰ at the surface and 34·69–35·72‰ at the bottom. Mean, 35·22‰.

(*c*) *Oxygen content*: 3·49–4·80 ml./L. (saturation, 75·83–106·13%). Mean, 3·94 ml./L. (saturation, 86·48%).

(*d*) *Phosphate-Phosphorus.*—0·334–0·805 *μg. at/L.* at the surface and 0·460–1·334 *μg. at/L.* at the bottom. Mean, 0·734 *μg. at/L.*

(*e*) *Nitrate-Nitrogen.*—Values show upward trend. 0·66–34·00 *μg. at/L.* at the surface and 2·49–8·20 *μg. at/L.* at the bottom. Mean, 9·436 *μg. at/L.*

(*f*) *Silicate-Silicon.*—7·73–13·06 *μg. at/L.* at the surface and 11·11–19·42 *μg. at/L.* at the bottom. Mean, 12·209 *μg. at/L.*

7. *Volume of plankton.*—Fluctuations common. Generally poor during the first half, but increases markedly in the latter half.

8. *Pigment units.*—830–2,900 units per haul. Mean, 2,060 units per haul.

9. *Dominant organisms.*—During the first fortnight, zooplankton dominates. In the latter half, phytoplankton begins to increase rapidly and there is an apparent decrease of zooplankters.

10. *General nature of phytoplankton.*—Diatoms dominant. Dinophyceæ common. Blue-green algæ occasionally seen.

11. *Dominant phytoplankters.—Chætoceros curvisetus. Lauderia annulata, Rhizosolenia stolterfothii, Chætoceros lorenzianus, Racteriastrum simplex, Bellerochea malleus, Schroederella delicatula, Sceletonema costatum, Thalassiosira subtilis, Chætoceros pelagicus, Fragilaria oceanica, Nitzschia seriata.*

June—

1. *Rainfall.*—Heavy rain throughout the month. 416·6–1,379·3 mm. Mean, 841·5 mm.

2. *Humidity.*—Air very humid. 88–93%. Average, 90%.

3. *Condition of the sea.*—Rough seas with heavy breakers. Water turbid.

4. *Wind.*—Strong winds from seaward, west. Velocity varies from 5·7–7·5 m.p.h. Mean, 6·6 m.p.h.

5. *Current.*—Not steady, direction varies frequently.

6. *Hydrological data.—*

(*a*) *Temperature*: (i) *Air.*—24·9–26·5° C. A fall from previous month. Mean, 25·7° C. (ii) *Sea-water.*—26·5–28·4° C. Average, 27·4° C.

(*b*) *Salinity*: A drop noticed, particularly at the surface. 22·67–34·62‰ at the surface and 34·03–35·43‰ at the bottom. Mean, 32·72‰.

(*c*) *Oxygen content*: 2·48–5·43 ml./L. (saturation, 50·71–106·20%) Mean 3·99 ml./L. (saturation, 81·83%).

(*d*) *Phosphate-Phosphorus*: 0·23–0·897 *µg. at/L.* at the surface and 0·288–2·036 *µg. at/L.* at the bottom. Mean, 0·863 *µg. at/L.*

(*e*) *Nitrate-Nitrogen*: 3·20–20·70 *µg. at/L.* at the surface. (Bottom values not available.) Mean, 8·812 *µg. at/L.*

(*f*) *Silicate-Silicon*: 12·50–29·50 *µg. at/L.* at the surface and 10·42–40·47 *µg. at/L.* at the bottom. Mean, 20·019 *µg. at/L.*

7. *Volume of plankton.*—Upward trend during the month, values high.

8. *Pigment units.*—1150 to 5150 units per haul. Mean, 2824 units.

9. *Dominant organisms.*—Phytoplankton dominant.

10. *General nature of phytoplankton.*—Diatoms dominant. Some species at times constituting the bulk. Dinophyceæ common. Blue-green algæ occasional.

11. *Dominant phytoplankters.—Sceletonema costatum, Fragilaria oceanica, Schræderella delicatula, Chætoceros socialis, C. curvisetus, Asterionella japonica, Lauderia annulata, Thalassiosira subtilis, Chætoceros lorenzianus, Nitzschia seriata, Thalassionema nitzschioides, Thalassiothrix frauenfeldii.*

July—

1. *Rainfall.*—Heavy rain throughout the month. 445·6–1,163·4 mm. Mean, 800·9 mm.

2. *Humidity.*—High. 92–96%. Mean, 93%.

3. *Condition of the sea.*—Rather rough with heavy breakers. Water turbid.

4. *Wind.*—From seaward. Velocity varies from 5·7–7 m.p.h. Mean, 6·2 m.p.h.

5. *Current.*—Not steady; direction varies frequently.

6. *Hydrological data.*—

(*a*) *Temperature*: (i) *Air.*—25·6–25·8° C. Mean, 25·7° C.

(ii) *Sea-water.*—Fall noticed. 24·9–26·3° C. Mean, 25·3° C.

(*b*) *Salinity*: 20·74–31·90‰ at the surface and 33·02–34·53‰ at the bottom. Mean, 30·90‰.

(*c*) *Oxygen content*: 3·51–6·03 ml./L. (Saturation 70·22–116·74%). Mean, 4·25 ml./L. (Saturation, 84·65%).

(*d*) *Phosphate-Phosphorus*: 0·564–1·369 *µg. at/L.* at the surface and 0·513–2·415 *µg. at/L.* at the bottom. Mean, 1·216 *µg. at/L.*

(*e*) *Nitrate-Nitrogen*: Values high during the month. 1·28–26·20 *µg. at/L.* at the surface. (Data for bottom not available.) Mean, 9·670 *µg. at/L.*

(*f*) *Silicate-Silicon*: 25·00–34·82 *µg. at/L.* at the surface and 16·67–31·89 *µg. at/L.* at the bottom. Mean, 27·204 *µg. at/L.*

7. *Volume of plankton.*—High values obtain.

8. *Pigment units.*—5,230–11,760 units per haul. Mean, 8,140 units.

9. *Dominant organisms.*—Phytoplankton dominates the bulk during the whole month, which reaches its peak of production.

10. *General nature of phytoplankton.*—Diatoms are the dominating elements of the bloom. At times one or two species far outnumber all others. Dinophyceæ common. Blue-green algæ often seen.

11. *Dominant phytoplankters.—Fragilaria oceanica, Asterionella japonica, Sceletonema costatum, Chætoceros curvisetus, C. brevis, C. lorenzianus, C. compressus, Coscinodiscus janischii, Actinoptychus undulatus, Biddulphia mobiliensis, Thalassiothrix frauenfeldii, Thalassionema nitzschioides.*

August—

1. *Rainfall.*—Rain decreases. 182·9–528·4 mm. Mean, 345·0 mm.

2. *Humidity.*—88–93%. Mean, 91%.

3. *Condition of the sea.*—Rough, but virulence less. Slightly turbid.

4. *Wind.*—From the sea with less force. Velocity varies from 5·3–6·5 m.p.h. Mean, 5·8 m.p.h.

5. *Current.*—Direction north-east to south-west; or sometimes south-east to north-west.

6. *Hydrological data.*—

(*a*) *Temperature*: (i) *Air.*—26–27·1° C. Mean, 26·55° C.

(ii) *Sea-water.*—24·3–26·5° C. Mean, 25·2° C.

(*b*) *Salinity.*—Increases. 28·35–32·77‰ at the surface and 34·08–34·88‰ at the bottom. Mean, 32·46‰.

(*c*) *Oxygen content.*—3·60–5·03 ml./L. (saturation, 72·78–98·16%). Mean, 4·10 ml./L. (saturation, 81·37%).

(*d*) *Phosphate-Phosphorus*: 0·495–1·932 *µg. at/L.* at the surface and 0·598–2·427 *µg. at/L.* at the bottom. Mean, 1·363 *µg. at/L.*

(*e*) *Nitrate-Nitrogen*: Values show a very marked downward trend. 0·47–9·80 *µg. at/L.* at the surface and 2·21–5·95 *µg. at/L.* at the bottom. Mean, 5·263 *µg. at/L.*

(*f*) *Silicate-Silicon*: 22·16–47·22 *µg. at/L.* at the surface and 20·77–33·54 *µg. at/L.* at the bottom. Mean, 29·488 *µg. at/L.*

7. *Volume of plankton.*—Slight diminution compared with last month.

8. *Pigment units.*—1,580–5,620 units per haul. Mean, 3,335 units.

9. *Dominant organisms.*—Phytoplankton constitutes the bulk. Zooplankton tends to increase.

10. *General nature of phytoplankton.*—Diatoms, the dominating flora. Dinophyceæ very common, occasionally *Noctiluca* in large quantities, dominating the plankton.

11. *Dominant phytoplankters.*—*Fragilaria oceanica, Asterionella japonica, Thalassiothrix frauenfeldii, Chætoceros lorenzianus, C. curvisetus, Coscinosira polychorda, Actinoptychus undulatus, Sceletonema costatum, Thalassiosira hyalina, Chætoceros mitra, C. brevis, Pleurosigma elongatum.*

September—

1. *Rainfall.*—Dminishes. 15·8–472·5 mm. Mean, 223·6 mm.

2. *Humidity.*—83–91%. Mean, 68%.

3. *Condition of the sea.*—Becomes calmer. Water clears.

4. *Wind.*—Variable, mostly from seaward. Velocity varies from 4·9–6·2 m.p.h. Mean, 5·6 m.p.h.

5. *Current.*—From north-east to south-west; at times north to south.

6. *Hydrological data.*—

(*a*) *Temperature*: (i) *Air.*—26·7–27·3° C. Mean, 27·0° C.

(ii) *Sea-water*: 24·5–26·2° C. Mean, 25·3° C.

(*b*) *Salinity*: 31·64–34·96‰ at the surface and 34·31–34·87‰ at the bottom. Mean, 33·95‰.

(*c*) *Oxygen content*: 2·97–4·97 ml./L. (saturation, 59·91–101·10%). Mean, 3·59 ml./L. (saturation, 72·68%).

(*d*) *Phosphate-Phosphorus*: 0·690–1·205 *µg. at/L.* at the surface and 0·851–1·564 *µg. at/L.* at the bottom. Mean, 1·078 *µg. at/L.*

(*e*) *Nitrate-Nitrogen*: 2·37–3·90 *µg. at/L.* at the surface and 0·36–1·20 *µg. at/L.* at the bottom. Mean, 2·140 *µg. at/L.*

(*f*) *Silicate-Silicon*: 15·11–40·58 *µg. at/L.* at the surface and 12·50–42·34 *µg. at/L.* at the bottom. Mean, 27·705 *µg. at/L.*

7. *Volume of plankton.*—Similar to August.

8. *Pigment units.*—Marked fluctuations. 480–6,000 units per haul. Mean, 2,908 units.

9. *Dominant organisms.*—Phytoplankton constitutes the bulk. Zooplankton on the increase.

10. *General nature of phytoplankton.*—Diatoms and dinophyceæ common. Swarms of certain Dinophyceæ or Chloromonadineæ may occur discolouring the water.

11. *Dominant phytoplankters.*—*Fragilaria oceanica, Chætoceros compressus, C. curvisetus, Rhizosolenia setigera, Chætoceros lorenzianus, C. decipiens, C. sociatis, C. didymus, Nitzschia seriata, Rhizosolenia alata* f. *gracillima, Chætoceros danicus, Thalassiosira decipiens.*

October—

1. *Rainfall.*—North-east monsoon begins, Scattered showers. 136·2–396·8 mm. Mean, 263·2 mm.

2. *Humidity.*—82–87%. Mean, 85%.

3. *Condition of the sea.*—Calm, occasionally rough.

4. *Wind.*—Mainly from north-east. Velocity varies from 5·5–7·9 m.p.h. Mean 6·2 m.p.h.

5. *Current.*—Mainly from south to north; at times south-east to north-east.

6. *Hydrological data.*—

(*a*) *Temperature* (i) *Air.*—26·8–27·4° C. Mean, 27·1° C.

(ii) *Sea-water.*—26·1–29·2° C. Mean, 27·5° C.

(*b*) *Salinity*: 30·46–33·83‰ at the surface and 33·94‰ at the bottom. Mean, 33·20‰.

(*c*) *Oxygen content*: 3·56–5·06 ml./*L.* (saturation 71·69–108·46%). Mean, 4·31 ml./L. (saturation, 92·12%).

(*d*) *Phosphate-Phosphorus*: 0·380–1·311 *μg.at/L.* at the surface and 0·575–1·539 *μg. at/L.* at the bottom. Mean, 0·949 *μg. at/L.*

(*e*) *Nitrate-Nitrogen*: Varies from 0·93–6·80 *μg. at/L.* at the surface and 4·30–12·71 *μg. at/L.* at the bottom. Mean, 5·007 *μg. at/L.*

(*f*) *Silicate-Silicon*: 9·60–31·96 *μg. at/L.* at the surface and 8·92–21·13 *μg. at/L.* at the bottom. Mean, 17·103 *μg. at/L.*

7. *Volume of plankton.*—Downward trend noticed.

8. *Pigment units.*—Downward trend. 780–2,230 units per haul. Mean, 1,286 units.

9. *Dominant organisms.*—Zooplankton prominent.

10. *General nature of phytoplankton.*—Diatoms and Dinophyceæ common. *Noctiluca* swarm common occasionally.

11. *Dominant phytoplankters.*—*Fragilaria oceanica, Chætoceros pelagicus, C. didymus, C. lorenzianus, C. lascinosus, C. compressus, Sceletonema costatum, Chætoceros curvisetus, Nitzschia seriata, Noctiluca miliaris, Thalassiothrix longissima, Chætoceros lauderi.*

November—

1. *Rainfall.*—2·6–165·7 mm. Mean, 62·8 mm.

2. *Humidity.*—77–81%. Mean, 78%.

3. *Condition of the sea.*—Calmer than last month. Water slightly turbid.

4. *Wind.*—From north or north-east. Somewhat strong. Velocity varies rom 5·4–6·2 m.p.h. Mean, 5·6 m.p.h.

5. *Current.*—From south-east to north-west; rarely north-east to south-east.

6. *Hydrological data.*—

(*a*) *Temperature*: (i) *Air.*—27·0–27·3° C. Mean, 27·15° C.

(ii) *Sea-water.*—27·8–29·4° C. Mean 28·5° C.

(*b*) *Salinity.*—31·36–34·5‰ at the surface and 33·69–34·84‰ at the bottom. Mean, 33·66‰.

(*c*) *Oxygen content.*—Values comparatively higher than previous month. 4·32–6·11 ml./L. (saturation, 92·60–128·65%). Mean, 4·88 ml./L. (saturation, 105·91%).

(*d*) *Phosphate-Phosphorus*: 0·311–1·449 *µg. at/L.* at the surface and 0·518–1·679 *µg. at/L.* at the bottom. Mean, 0·989 *µg. at/L.*

(*e*) *Nitrate-Nitrogen*: 2·37–10·78 *µg. at/L.* at the surface and 5·60–9·62 *µg. at/L.* at the bottom. Mean, 6·474 *µg. at/L.*

(*f*) *Silicate-Silicon*: 7·96–22·90 *µg. at/L.* at the surface and 7·58–28·50 *µg. at/L.* at the bottom. Mean, 12·90 *µg. at/L.*

7. *Volume of plankton.*—Downward trend. Poor values.

8. *Pigment units.*—760–2,680 units per haul. Mean, 1,751 units.

9. *Dominant organisms.*—Zooplankton dominant.

10. *General nature of phytoplankton.*—Diatoms and Dinophyceans common. *Noctiluca* in swarms at times.

11. *Dominant phytoplankters.*—*Chætoceros lorenzianus, C. curvisetus, C. compressus, Fragilaria oceanica, Chætoceros affinis, Ornithocercus magnificus, Nitzschia seriata, Chætoceros socialis, Nitzschia sigma* var. *indica, Asterionella japonica, Chætoceros lascinisus, Ceratium tripos.*

December—

1. *Rainfall.*—0·00–94 mm. Mean, 28·0 mm.

2. *Humidity.*—92–77%. Mean, 74%.

3. *Condition of the sea.*—Calm. Water clear.

4. *Wind.*—Mainly from north or north-east. Velocity varies from 5·5–6·0 m.p.h. Mean, 5·7 m.p.h.

5. *Current.*—From north-east to south-west or north to south.

6. *Hydrological data.*—

(*a*) *Temperature*: (i) *Air.*—26·2–27·1° C. Mean, 26·65° C.

(ii) *Sea-water*: 27·5–28·4° C. Mean, 28·1° C.

(*b*) *Salinity*: 32·08–34·19‰ at the surface and 32·08–34·63‰ at the bottom. Mean 33·55‰.

(*c*) *Oxygen content*: 4·07–4·67 ml./L. (saturation, 86·80–98·40%). Mean 4·34 ml./L. (saturation, 92·01%).

(*d*) *Phosphate-Phosphorus*: 0·414–0·966 *µg. at/L.* at the surface and 0·288–1·173 *µg. at/L.* at the bottom. Mean, 0·710 *µg. at/L.*

(*e*) *Nitrate-Nitrogen*: 2·20–10·00 *µg. at/L.* at the surface and 2·97–5·90 *µg. at/L.* at the bottom. Mean, 5·221 *µg. at/L.*

(*f*) *Silicate-Silicon*: 5·17–18·75 *µg. at/L.* at the surface and 5·30–21·54 *µg. at/L.* at the bottom. Mean, 12·289 *µg. at/L.*

7. *Volume of plankton.*—Values poor.

8. *Pigment units.*—Vary from 530–2,590 units per haul. Mean, 1,525 units.

9. *Dominant organisms.*—Zooplankton dominant.

10. *General nature of phytoplankton.*—Diatoms and Dinophyceæ common.

11. *Dominant phytoplankters.—Chætoceros lascinosus, C. lorenzianus, Fragilaria oceanica, Chætoceros curvisetus, C. compressus, Sceletonema costatum, Chætoceros contortum, C. filiferum, Ornithocercus magnificus, Chætoceros socialis, Bacteriastrum hyalinum* var. *princeps, Peridinium depressum.*

General Remarks

In the earlier accounts of this series (Subrahmanyan, 1958 *a*; 1959 *a, b*) the seasonal quantitative fluctuation of the total crop of phytoplankton and the magnitude of its production and related factors were discussed. The data presented in this account show the nature and quantitative variation of the constituent elements of the phytoplankton crop through the different months of the year.

In the course of over five years, about 29 species of Bacillariophyceae, 7 species of Dinophyceæ and one of Cyanophyceæ have been recorded under dominant forms (a very small proportion only compared with a total of 226 species of the Bacillariophyceæ, 120 species of the Dinophyceæ and 7 of Cyanophyceæ *vide* Subrahmanyan, 1958 *b*), some of which contribute to the bulk of the flora during the different months of the year. Whether the order of ranking shown here would be constant every year for the months concerned cannot be stated with certainty as the abundance of each is governed by many factors although the ranking shown is based on five years' averages. The relative abundance of each species will be decided by the nature and the span of its life-cycle which brings about a cyclical abundance

in its occurrence as shown for *Fragilaria oceanica* by Subrahmanyan (1959 *a*, *b*). Particulars regarding fluctuations of individual species are available for some from Indian waters (Subrahmanyan, 1954 *a*, *b*) and also elsewhere (Wimpenny, 1936, 1946, 1956; Cushing, 1956).

In this connection, it may be mentioned that the importance of mass forms has been stressed by Zenkevitch (1958) also. He also states that the number of such mass forms which consummate 70–80% of the total biologial processes is not likely to be very large and for plankton these may be only 20–30 forms. The present investigation also shows that 29 species of diatoms and 7 of Dinophyceæ (the latter is only of secondary importance) and one of Cyanophyceæ go to constitute the bulk (over 1,000,000 cells per vertical net haul) of the flora on the west coast of India (*refer* Table II). Nevertheless, it may be mentioned here that the possibiity exists whereby the paucity of many or some of the species at least could be due to their depletion by

TABLE II

List of "Mass Forms"

	BACILLARIOPHYCEÆ
1	*Asterionella japonica*
2	*Bacteriastrum hyalinum* var. *princeps*
3	*Biddulphia heteroceros*
4	*B. mobiliensis*
5	*Chætoceros affinis*
6	*C. brevis*
7	*C. compressus*
8	*C. contortum*
9	*C. curvisetus*
10	*C. lasciniosus*
11	*C. lauderii*
12	*C. lorenzianus*
13	*C. pelagicus*
14	*C. socialis*
15	*Coscinodiscus asteromphalus*
16	*C. oculus-iridis*
17	*Fragilaria oceanica*
18	*Guinardia flaccida*
19	*Lauderia annulata*
20	*Leptocylindrus danicus*
21	*Nitzschia seriata*
22	*N. sigma* var. *indica*
23	*Rhizosolenia alata*
24	*R. robusta*
25	*R. stolterfothii*
26	*Sceletonema costatum*
27	*Schrödereila delicatula*
28	*Thalassiothrix frauenfeldii*
29	*T. longissima*
	DINOPHYCEÆ
1	*Ceratium fuscus*
2	*C. macroceros*
3	*C. tripos*
4	*Dinophysis caudata*
5	*Glenodinium lenticula* f. *asymmetrica*
6	*Noctiluca miliaris*
7	*Peridinium depressum*
	MYXOPHYCEÆ
1	*Trichodesmium erythræum*

predators. Apparently, therefore, the scarcity of species in the waters should not lead to their being ignored.

One interesting point may be mentioned here. The highest number of species record in any month was 190 and the lowest 140. It would appear that always a good number of species are represented in the water, the variation being in the quantity of one or the other according to the seasons and factors affecting individual species.

Summary

The seasonal distribution of the various phytoplankters on the west coast of India is given with indications as to their frequency of occurrence as also a catalogue of the relevant physical and chemical factors. It is shown that as against a total recorded species of 226 Bacillariophyceæ, 120 of Dinophyceæ, and 7 of Cyanophyceæ, only 29 of the Bacillariophyceæ, 7 of the Dinophyceæ, and 1 of the Cyanophyceæ are of consequence as regards bulk of occurrence and these are pointed out. A table is also given to indicate the relative distribution of all the species through the year.

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NOTES ON EGGS, LARVAE AND JUVENILES OF FISHES FROM INDIAN WATERS

VI. Genus *Auxis* Cuvier. VII. *Sarda orientalis* (Temminck & Schlegel)

By S. Jones

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VI. Genus *Auxis* Cuvier

There are under this genus two distinct species distinguished mainly by the nature of their corselets. In the first species, *A. thazard* the corselet is short, abruptly constricting immediately behind the vertical from the hind end of the first dorsal, whereas in the second species it gradually tapers and extends to well behind the second dorsal. Bleeker described *A. tapeinosoma* (Bleeker, 1854), and *A. thynnoides* (Bleeker, 1855) from Indonesian waters and these have been relegated as synonyms of *A. thazard* by Beaufort (1951). Wade (1949), while working on Philippine tunas, recognised the presence of a long corseletted form distinct from the short corseletted form and fixed the identity of the former as *A. tapeinosoma*, a name used by subsequent workers (Herre and Herald 1951; Herre, 1953; Jones, 1958). Recently Matsumoto (1959) after a critical study of the original descriptions and examination of the type specimens of both *A. tapeinosoma* and *A. thynnoides* found that the former is a short corseletted form and as such is synonymous with *A. thazard*, while the latter is a long corseletted form. Therefore in this account *A. tapeinosoma* is relegated as a synonym of *A. thazard* and the long corseletted form will be referred to as *A. thynnoides*. Both the species are distributed in the Indo-Pacific but the former appears to be better known and from a wider area than the latter.

Larval Auxis

Auxis larvæ could be distinguished from the larvæ of other thunnids by the presence of conspicuous chromatophores along the mid-ventral and mid-dorsal lines of the caudal peduncle. Chromatophores develop along the mid-lateral line of the caudal peduncle also in the older specimens. There is close similarity between the early larvæ of *Euthynnus* and *Auxis* and the characters which would enable them to be distinguished from one another have already been detailed by Wade (1951) and Matsumoto (1958).

There are in all 9 larvæ in the collection ranging in total length from 3·36 mm. to 7·94 mm. which could be assigned to the genus *Auxis* but their specific identity is not known. All the specimens have been collected from the Laccadive Sea and their measurements and other particulars are given in Table I.

TABLE I

Measurements *of* Auxis *Larvae in mm.*

Sl. No.	Date	Station	T.L.	St. L.	Head	Max. W.	Snout	Eye	Sn. to D.	Sn. to V.
1*	10-4-1959	436	3·36	3·20	1·03	·97	·31	·34	·91	1·38
2	29-4-1959	448	3·37	3·25	·97	·91	·31	·34	·91	1·42
3	29-4-1959	448	3·65	3·54	1·20	1·14	·34	·40	1·14	1·59
4	28-4-1959	447	3·65	3·48	1·20	1·03	·34	·40	1·20	1·59
5	10-4-1959	436	4·34	4·11	1 50	1·31	·51	·46	1·60	2·11
6*	6-1-1959	73°·07′ E. 8°·40′ N.	4·40	4·17	1·49	1·37	·54	·49	1·71	2·17
7*	29-4-1959	448	5·08	4·85	1·88	..	·57	·57	1·94	2·28
8	6-1-1959	73°·07′ E. 8°·40′ N.	5·20	4·80	1·83	1·60	·60	·53	1·94	2·39
9*	Do.	Do.	7·94	6·85	2·85	2·22	1·08	·90	2·91	3·77

* Denotes specimens described and figured.

T., Total, L., Length, St., Standard, Max. W., Maximum width, Sn., Snout, D., Dorsal., V., Ventral.

3·36 *mm. larva* (Fig. 1).—This is the smallest larva in the series and was collected from *Kalava* station No. 436 on 10–4–1959 and is provisionally

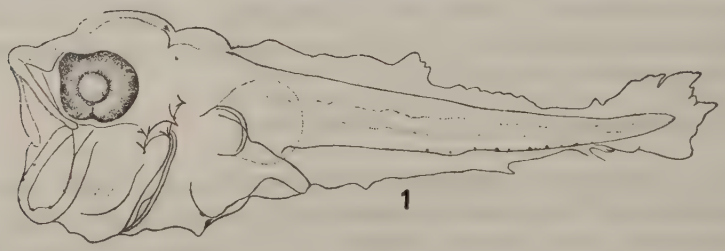
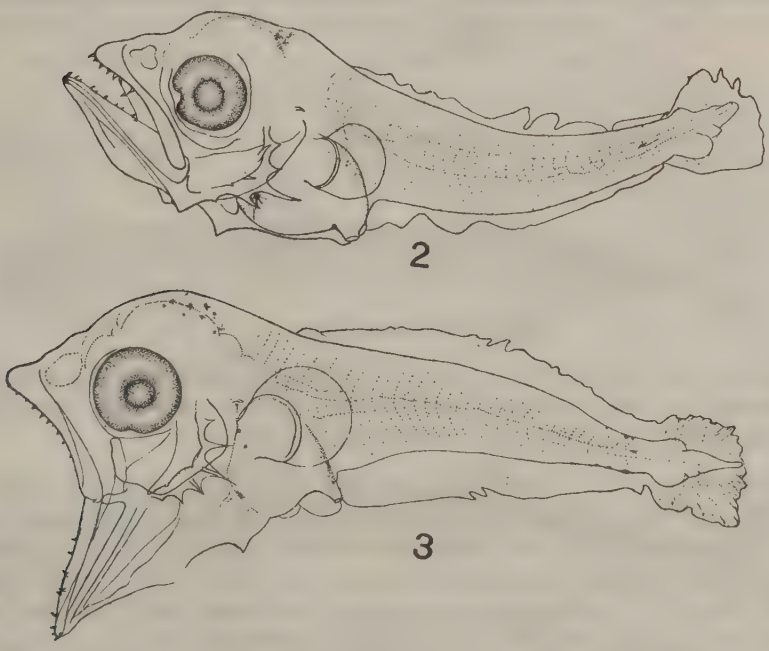


FIG. 1. 3·36 mm. *Auxis* larva.

assigned to *Auxis*. The snout and median fins are somewhat distorted and teeth are absent but the general features leave no doubt of its being a larval thunnid. The preopercular spines are three in number and are all more

or less of the same size at this stage whereas at the subsequent stage there are five in all and the central one becomes conspicuously larger than the rest. Though the characteristic chromatophores on the caudal peduncle are absent, evidently due to its being a very early larva, the presence of a row of chromatophores along the ventral side of the body, the distribution of the chromatophores on the head and absence of any pigment on the side of the lower jaw helps to place it provisionally as an *Auxis* larva.

4·40 *mm. larva* (Fig. 2).—This specimen was collected from 73°·07′ E. and 8°·40′ N. on 6–1–1959 on board *I.N.S. Jumna*. Chromatophores at



FIGS. 2 and 3. *Auxis* larvae 4·40 mm. and 5·08 mm. respectively.

the caudal peduncle, characteristic of the *Auxis* larvae are present. There is a group of chromatophores on the head over the region of the mid-brain and a single one at the tip of the lower jaw. The one at the symphysis of the pectoral girdle is more conspicuous than in the previous stage and more of them are seen in the abdominal region.

Teeth are present in both the jaws. In addition to the preopercular spines a small spinous growth is discernible immediately above the angle

of the operculam at the post-temporal region. The median fins which appear frayed due to shrinkage are devoid of rays and the myomeres at the caudal end are not distinct.

5·08 *mm. larva* (Fig. 3).—This is a slightly older stage than the previous one. The row of chromatophores on the ventral side has disappeared except at the caudal peduncle where they are more conspicuous than in the previous stage. The disposition of the other chromatophores is more or less the same. There are faint indications of rays in the median finfold.

7·94 *mm. larva* (Fig. 4).—This is a distinctly more advanced stage than the previous ones described. A distinct row of chromatophores have

FIG. 4. 7·94 mm. *Auxis* larva.

developed on each side of the caudal peduncle making the characteristic pigmentation there markedly conspicuous. There are more chromatophores on the head and in the abdominal region.

The specimen is proportionately broader. Pelvic fins are present and all the fins possess spines and rays as the case may be, though the full complement has not developed in the dorsal and anal fins. All the median fins are still connected by narrow fin folds. The preanal finfold is still present. The wide gap between the two dorsals which are still connected by a narrow finfold which does not show any indication of spines or rays distinguishes the advanced larvæ of *Auxis* from larvæ of other thunnids of corresponding size (Wade, 1951; Matsumoto, 1958 and 1959 and Jones, 1959 and 1960).

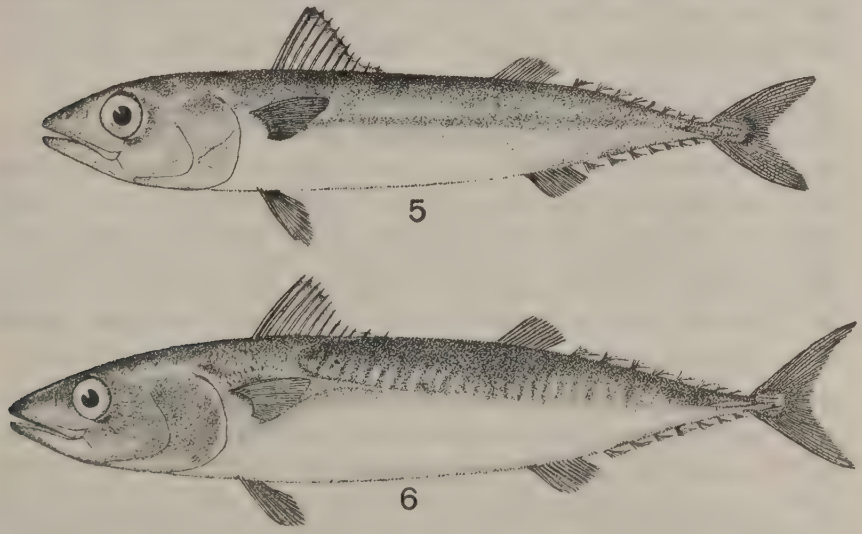
So far characters distinguishing the larvæ of *Auxis thazard* from those of *A. thynnoides* have not been properly delineated though Ehrenbaum (1924) has given descriptions of *A. thazard* from the Mediterranean where only this species occurs. Larval *Auxis* have been described from the Pacific by Wade, 1951, Matsumoto, 1958 and 1959 but their specific identity does

not appear to be certain since both the species occur there. Though both the species occur in the Indian waters so far only *A. thazard* has been recorded from the Laccadive Sea from where these specimens have been collected and the possibility is that the larvae described could be of this species. But the chances of *A. thynnoides* also occurring there are equal and therefore any inference could only be tentative.

Juveniles of Auxis thynnoides *Bleeker*

There are in all 26 juveniles in the collection measuring from 44 mm. to 209·8 mm. Of these the measurements of 20 are given in Table II. All the specimens have been collected from Vizhingam on the west coast and so far specimens within the above length range have not been obtained from any other locality.

46·8 *mm. Juvenile* (Fig. 5).—This has a total length of 53 mm. and is one of the smallest among the juveniles collected and is listed as No. 3



FIGS. 5 and 6. Juvenile *Auxis thynnoides* 46·8 mm. and 79·50 mm. respectively.

in the series in Table II. The corselet scales have not developed and the lateral lines are also absent. The colour is dark brown above and whitish below.

The wide gap between the two dorsal fins in combination with other characters places it as an *Auxis* and comparison with the graded series available shows that it is *A. thynnoides*.

TABLE II

Measurements of Juveniles Auxis thynnoides *Bleeker in mm.*

Sl. No.	Date	Std. L.	Head	Snout	Eye	Maxilla	Max. depth.	Sn. to D.	Sn. to A.	D. spine L.	Gill-rakers
1	?	44·0	13·0	4·0	3·5	5·4	8·5	15·0	30·0	4·6	..
2	29—5–1958	46·7	13·8	4·4	3·4	5·7	8·2	16·2	33·2	5·8	7+20
3*	29—5–1958	46·8	14·0	4·1	3·2	5·5	8·6	16·3	33·9	5·0	7+20
4	?	48·0	13·9	4·4	3·5	5·8	8·4	16·2	33·6	5·8	8+22
5	26—3–1959	49·2	15·1	4·4	3·3	6·1	8·9	17·3	35·7	5·2	8+21
6	26—3–1959	61·7	17·4	5·7	3·9	7·0	11·2	21·0	42·3	6·2	8+22
7	26—3–1959	67·0	19·2	6·2	4·0	8·0	12·0	23·0	46·2	7·5	8+23
8	?	69·2	18·8	5·9	4·1	7·5	12·8	22·5	47·2	7·3	8+26
9*	26—3–1959	79·5	22·0	6·3	4·5	8·1	14·7	26·1	55·0	8·0	9+31
10*	30—9–1958	125·0	33·0	9·8	6·1	12·0	22·0	38·5	85·0	12·6	9+31
11	?	126·1	33·7	10·1	7·0	13·0	21·8	38·8	87·0	14·0	..
12	30—9–1958	128·5	33·8	10·2	6·3	12·8	23·0	41·0	89·2	13·7	10+31
14	30—9–1958	132·0	35·0	10·4	6·4	12·9	23·3	41·0	89·4	14·8	10+30
17	30—9–1958	181·0	48·0	13·5	9·0	15·7	34·0	55·3	131·1	16·5	10+36
19	30—9–1958	183·0	49·0	11·8	11·0	16·5	36·0	51·2	128·0	20·0	11+35
20*	30—9–1958	185·3	46·7	11·9	9·0	15·3	33·8	57·0	131·5	16·8	11+35
21	30—9–1958	187·5	49·0	12·0	10·0	16·5	36·0	59·5	131·9	19·0	10+34
22	3–10–1958	189·0	49·0	12·4	9·0	15·5	36·0	59·7	134·0	18·7	11+34
23	3–10–1958	191·0	50·1	12·8	9·2	16·0	36·2	59·5	134·5	19·5	10+35
24	3–10–1958	196·0	51·5	13·2	10·2	17·2	36·0	62·5	142·0	19·2	10 36
25	3–10–1958	205·2	51·5	12·5	9·2	16·0	38·0	61·0	139·5	20·2	11+34
26	3–10–1958	209·8	55·8	14·0	10·5	17·2	41·0	65·6	150·2	22·2	10+36

* Denotes specimens described and figured.

?, Dates of Collection not known. Std., Standard. L., Length. Sn., Snout. D., Dorsal. A., Anal.

79·50 *mm. Juvenile* (Fig. 6).—This has a total length of 87 mm. and was collected from Vizhingam on 26–3–1959. The corselet scale extends vertical to the first dorsal fin. The lateral line is incomplete and does not extend to the caudal region. The dorsal half bears indistinct oblique dark

lines. The general colouration is darker than in the previous stage described.

125 *mm. Juvenile* (Fig. 7).—This has a total length of 136 mm. and was collected from Vizhingam on 30–9–1958. The corselet scales are better developed but they extend only up to midway between the dorsals. The lateral line is complete. The general colouration is darker than in the previous stage described.

185·3 *mm. Juvenile* (Fig. 8).—This has a total length of 198·5 mm. and was collected from Vizhingam on 30–9–1958. The corselet scales extend to behind the second dorsal and specimen though immature has all the unmistakable features of adult *A. thynnoides.*

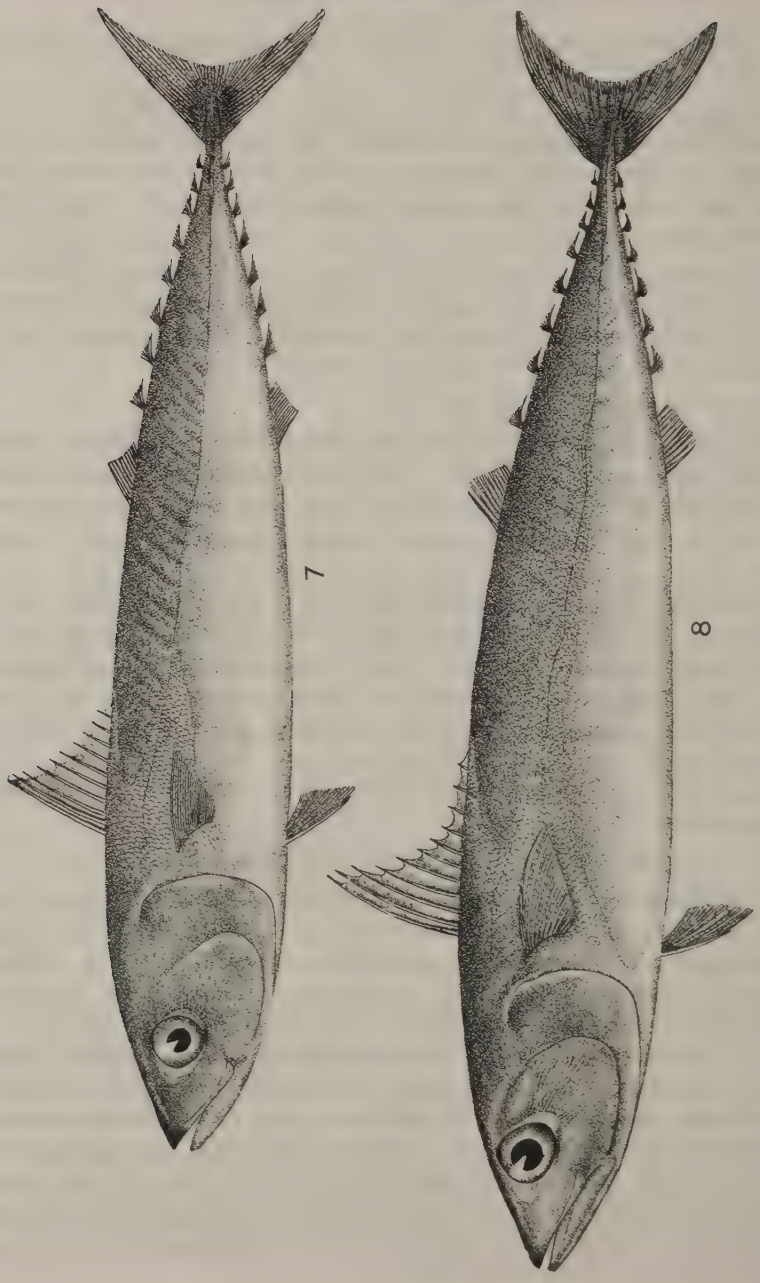
Juvenile of Auxis thazard (*Lacépède*)

Juveniles of *Auxis thazard* have been described from the western Pacific by Wade (1951) and Mead (1951). Though the adults of this species have been recorded from more localities in the Indian region than its congener only a single juvenile specimen described below has been obtained so far.

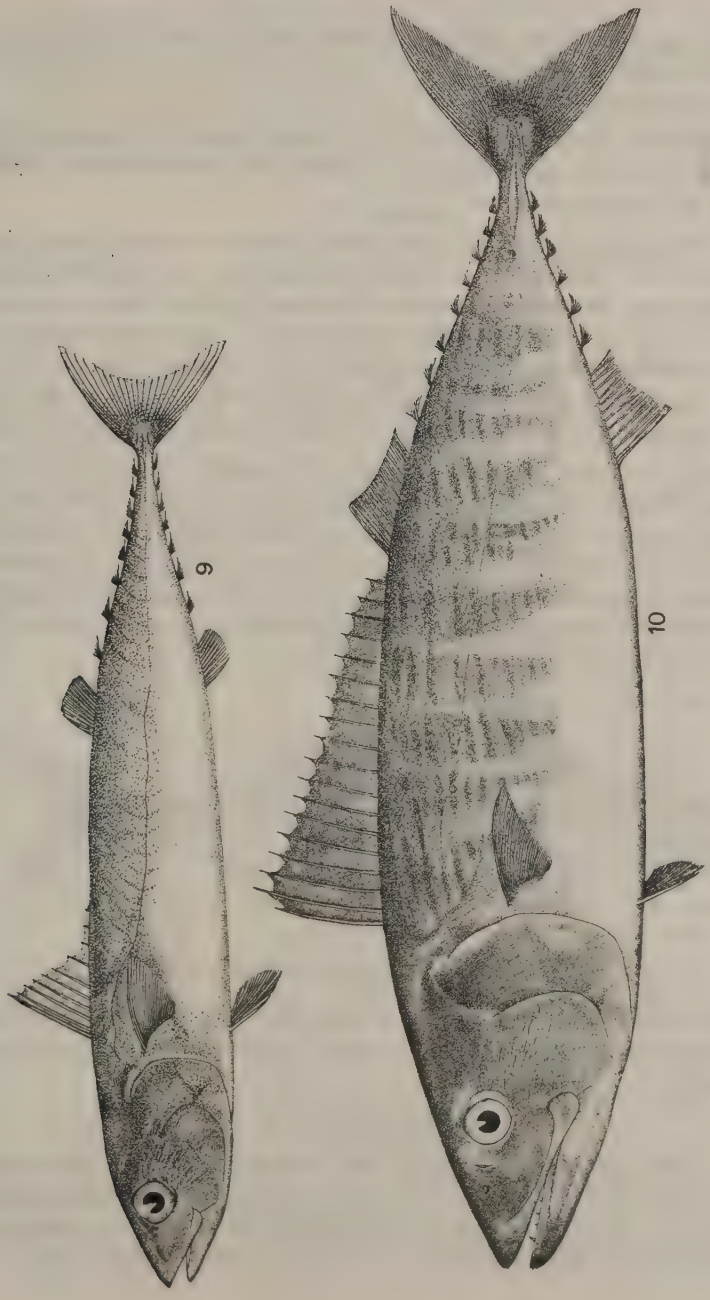
118 *mm. Juvenile* (Fig. 9).—This has a total length of 131 mm. and a reference about this has already been made by the author in an earlier article (Jones, 1958). This was collected by Mr. S. Iswaramurthy of this Research Station who found it washed ashore at Mandapam Camp on 26–5–1956. The specimen is large enough to be distinguished from the juvenile of *A. thynnoides* of the same length by its more compressed body, rather tapering caudal region and abruptly narrowing corselet of scales bordering the lateral line.

VII. *Sarda orientalis* (Temminck & Schlegel)

Three valid species are recognised (Fraser-Brunner, 1950) under the genus *Sarda*, *viz.*, *S. chilensis*, *S. sarda* and *S. orientalis*, the last one being the species occurring here though according to Day (1878) it is *S. chilensis* (= *pelamys chilensis*). *S. orientalis* has a wide distribution in the Indo-Pacific from the East Coast of Africa to the West Coast of America. It grows to a length of over half a metre and does not form a regular fishery of any appreciable magnitude anywhere. Usually it is caught in stray numbers along with other fishes though occasionally juveniles come in shoals as in November 1959 when large catches of specimens ranging in length between 160 mm. and 200 mm. were reported from some fishing centres between Trivandrum and Cape Comorin on the west coast. Larger specimens are caught in hook and line and gill nets whereas the juveniles are caught in shore-seines and boat-seines.



FIGS. 7 and 8. Juvenile *Auxis thynnoides* 125 mm. and 185·3 mm. respectively.



FIGS. 9 and 10. Fig. 9. Juvenile *Auxis thazard* 118 mm. and Fig. 10. Juvenile *Sarda orientalis* 158 mm.

There appears to be little information on the development of fishes of the genus *Sarda* except the observations on the larvæ of *S. sarda* by Ehrenbaum (1924).

The smallest specimen available is a juvenile 80 mm. in standard length and 89 mm. in total length (Fig. 11) collected from Vizhingam near Trivandrum on the west coast.

The body bears twelve transverse bands which are broad at the dorsal aspect and taper laterally to become imperceptible on reaching the sides of the abdomen and above the anal. The jaws possess small teeth. The eyes are comparatively larger and head larger in proportion to the head and body length respectively than in the adult. Conspicuous even in the juvenile stage is the wide cleft of the mouth and the posterior end of the maxilla surpassing a vertical line below the posterior end of the orbit.

One of the larger juvenile specimens measuring 158 mm. in standard length and 174 mm. in total length collected from Vizhingam during November 1959 is given in Fig. 10. The transverse bands referred to the previous stage have subdivided into more or less horizontal streak, which untimately unite to give rise to the lines so characteristic in the adult. In a specimen 262 mm. in total length all the lines immediately above the pectoral fins have already been formed as in the adult.

FIG. 11. Juvenile *Sarda orientalis* 80 mm.

The food of juvenile *S. orientalis* consists of larval and juvenile fishes and crustaceans. Adults feed on young and small-sized fishes, crustaceans and squids.

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board *I.N.S. Jumna*. The juvenile specimens were collected by the various members of the staff of the Central Marine Fisheries Research Centre at Vizhinjam to whom my thanks are due. I am grateful to Messrs. M. Kumaran and Egbert Dawson for the very valuable help given in the preparation of the tables and diagrams.

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THE FISHERIES OF MALWAN

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Introduction

Malwan is one of the important fishing centres on the west coast and it is situated at almost the northern limit up to which the exploitation of the economically important mackerel and oil-sardine fisheries of the west coast extends. In spite of its importance there is hardly any information on the fisheries of this place; and the present work was undertaken with a view to fill this gap in our knowledge of the conditions existing in the major fishing centres of the west coast. The following pages give the result of the fishery survey work carried on at Malwan for a period of six years from 1950 to 1957 (with a gap during 1953 and 1954 when no data were collected). In computing the data the "random sampling" method was used for estimating the total catch, unit-effort, etc.

Malwan (lat. 16° 03′ N., long. 73° 26′ E) situated about 180 miles south of Bombay, is the taluk headquarters in the Ratnagiri District (Fig. 1). There are four fishing hamlets in the coastal area of Malwan, namely, Dhuriwada, Medha, Rewatala and Wairi-Dandi (Text-Fig. 1 inset). Throughout the Ratnagiri District the shore is very narrow and in many places the hills of the Western Ghats come up to the very edge of the sea. Malwan is an exception to this in having a good shore, about nine miles long, stretching from Malwan in the north to Mobar in the south, and more intensive fishing is carried out here than in any other part of the district. The inshore region of the sea is generally sandy and slopes rather steeply, the five-fathom line being only 20 yards from the shore. Beyond this limit the sea-bed is rocky along the entire nine miles stretch and the rocks jut out from the sea. These topographical peculiarities have influenced the shape and size of the nets of this locality especially the shore seine known as the *rampan*, which is broader and has at the most 100 pieces of net. The drift nets are represented in this area by the (1) *Saranga jal*, (2) *Dhangad*, (3) *Surmai jal*, (4) *Kandali* and (5) *Wavvari*. Only one type of boat-seine and gill net, called, the *Jot* and *Bangada jal* respectively are represented here while a number of cast nets bearing different names depending upon the mesh are used. Thus the *Bangada pag*, an unstringed cast net and the stringed variation of

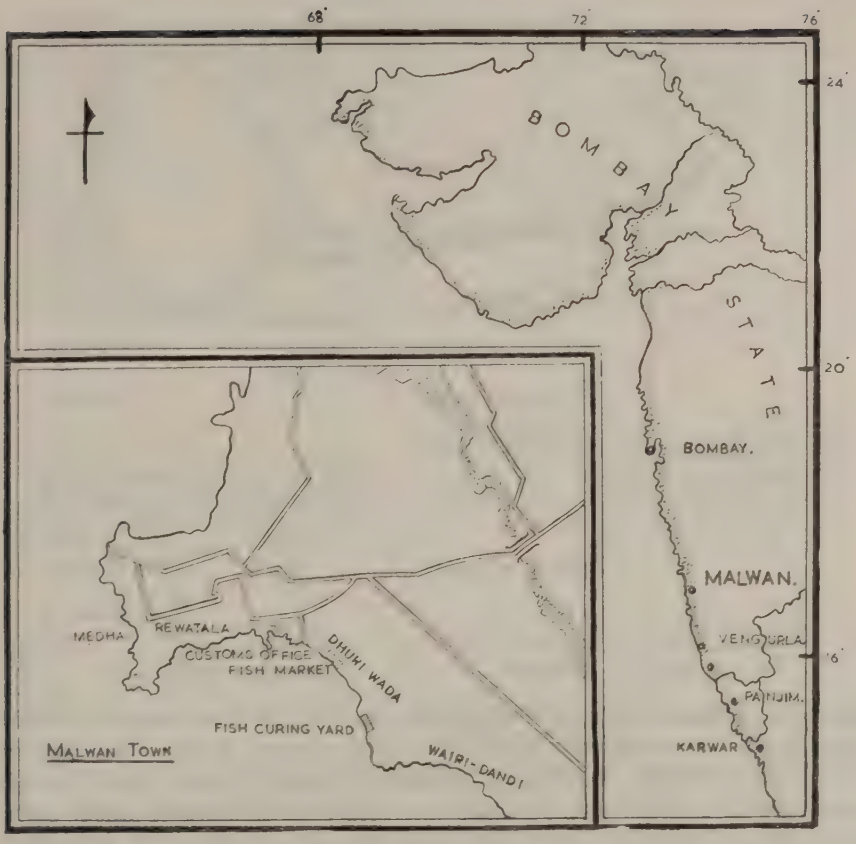


FIG. 1. Sketch map showing location of Malwan. Inset—Malwan town and neighbourhood.

the same called *Shendi*, both of 1″ mesh, is used for catching mackerel. The other cast nets are the *Pharaon* (¾″ mesh) used for sardines, *Leiognathus*, *Ambassis*, etc., *dod pag* (½″ mesh) and *aad pag* (¼″ mesh) used during the quiet spells in the monsoon close to the shore to catch the fry of the fish for one's own culinary purposes. Lines of the *cheira bepu* type of the Malabar coast are also operated at Malwan. These nets are operated from two types of boats, namely, the dug-out canoe and the out-rigger boat (Text-Figs. 2 and 3). The dug-out canoe measures 11′ × 3′ × 2′ and is used for operating the drift net, cast net, and the line, while the smaller sized out-rigger of 36′ × 5′ × 4′ is used for operating the gill net and the *dhangad*; the bigger out-rigger measuring 48′ × 6′ × 5′ is used for operating the *rampan* and the

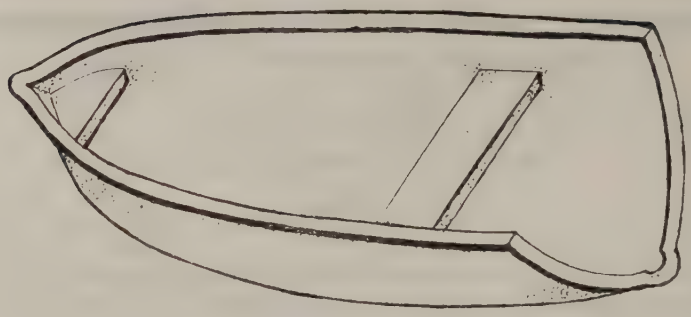


FIG. 2. Keeled Dugout (Malwan).

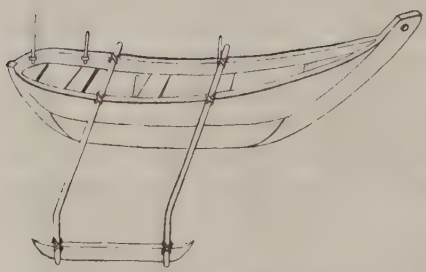
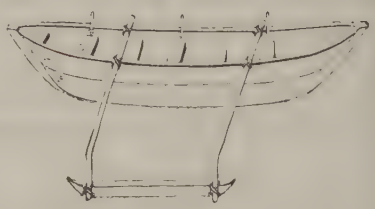


FIG. 3. Out-rigger (Malwan).



Out-rigger (Karwar).

jot. As the details of construction cost, etc., of the boats appear in other papers they have not been given here. The number of boats and gear in the different hamlets of Malwan are given in Table I, while Table II shows the seasons of operation and the fishes caught in the different gears. The fishermen of Rewatala do not own either boats or nets, but work in partnership with the fishermen of Dhuriwada and Wairi-Dandi.

TABLE I

Hamlet	Boat			Gear					
	Rampan	Out-rigger	Canoe	*Rampan*	Drift net	Gill net	Dhangad	Line	Jot
Medha	..	3	16	..	16	3	2	10	..
Wairi-Dandi	7	24	26	7	20	..	6	10	7
Dhuriwada	2	7	10	2	10	..	3	10	..

TABLE II

Gear	Season of operation	Fishes caught
Shore-seine		
Rampan ..	Sept.–May	All fishes that come near shore
Drift net—		
Surmai jal ..	March–May & Sept.–Dec.	*Scomberomorous, Chirocentrus*
Saranga jal ..	,, ,,	Pomfrets
Kandali ..	,, ,,	Smaller pomfrets
Wawari ..	,, ,,	*Scomberomorous* and pomfrets
Dhangad ..	,, ,,	*Scomberomorus, Sciæna,* sharks
Gill net—		
Bangada jal ..	March	*Rastrelliger canagurta*
Boat-seine—		
Jot ..	Sept.–Oct.	*Sciæna, Arius*
Lines—		
Wawadi ..	Sept.–May	Carcharhindidae, *Scoliodon, Sphyrna, Pastinachus, Muræsox*

ANALYSES OF LANDINGS

Design of Survey and Method of Analyses.—Based on the information collected during the preliminary survey of 1948–49, the plan of estimating the total landings of fish and their composition was finalised and put into operation from 1950. In accordance with the plan Malwan was visited once a fortnight, the duration of each stay being about 5–7 days. During each day of observation the total number of different units* landing their catch was ascertained, a fixed percentage of each type of unit was examined in detail to determine the species composition of the catch, together with their weight. The total catch and its composition were estimated based on the average number of units and their average catch per day.

* A unit denotes one type of boat operating one type of net. Thus, a canoe operating a drift net is one unit; a canoe operating a line is another unit; an out-rigger operating a *rampan* is a third unit; and so on.

Analyses of Estimated Landings.—The estimated total landings of the fish for the six years 1950 to 1952 and 1955 to 1957 (data not having been collected for 1953 and 1954) are shown in Table III and the composition of the catch according to the type of fishing unit in Table IV. The monthly fluctuations in the catch for these six years are shown in Table V and Fig. 4. (In the tables and the body of the paper tons mean metric tons, except where otherwise stated.)

TABLE III

Year	Catch (Tons)	Year	Catch (Tons)
1950	681·51	1955	438·79
1951	727·14	1956	907·38
1952	536·06	1957	1140·77

TABLE IV

Year	*Rampan*	Drift net	Line	Boat-seine	Others	Total (tons)
1950	296·95	20·94	8·62	352·98	2·01	681·50
1951	657·03	28·15	34·68	..	7·28	727·14
1952	194·26	11·47	26·48	303·85	..	536·06
1955	272·82	19·93	142·47	..	3·57	438·79
1956	592·33	104·84	196·37	9·87	3·97	907·38
1957	748·65	21·55	368·05	2·32	0·19	1140·76

It will be seen from the above figures that there is a marked fluctuation during these years. In 1950 the total catch was 681·50 tons. Of this 352·98 tons were landed by boat-seines, 296·95 tons by *rampans*, 20·94 tons by drift nets and 8·62 tons by lines. In 1951 the total catch increased to 727·14 tons. Almost 90% of this was landed by the *rampans* (657·03 tons) while the rest was landed by the drift nets (28·15 tons) and lines (34·68 tons). Boat-seines were a total failure during 1951. In 1952 the total catch (536·06

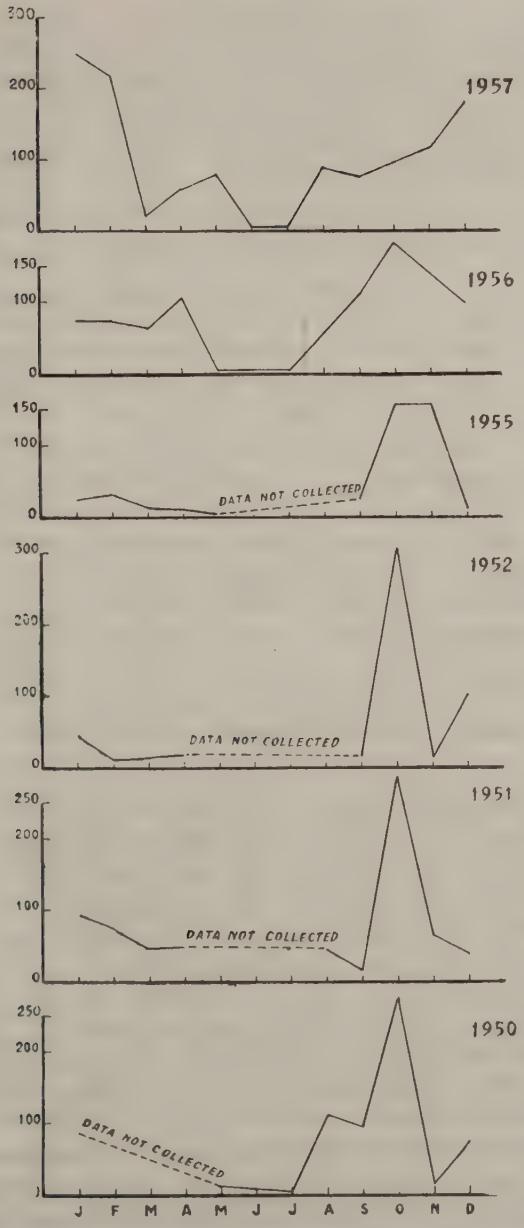


FIG. 4. Monthly fluctuations in fish-catches at Malwan (in metric tons).

TABLE V

Month	1950	1951	1952	1955	1956	1957
January ..	86·39	96·36	47·44	23·93	76·18	203·74
February ..	..	73·86	10·04	31·64	76·29	222·29
March ..	..	47·73	..	13·10	64·29	21·60
April ..	..	44·63	11·00	11·28	109·25	57·58
May ..	9·92	..	22·69	1·13	1·31	72·65
June ..	3·57	..	..	..	0·15	1·33
July ..	1·11	..	..	..	0·95	0·17
August ..	111·22	43·95	..	..	59·69	88·08
September ..	96·33	18·31	15·77	23·97	109·77	76·53
October ..	278·19	292·19	314·84	161·38	185·28	94·99
November ..	16·48	70·43	13·14	155·57	125·05	120·17
December ..	78·30	39·73	101·14	16·79	99·17	181·67
TOTAL ..	681·51	727·19	536·06	438·79	907·38	1140·76

tons) showed considerable decline, the worst affected being the rampan (194·26 tons), and drift nets (11·47 tons), while the line catch (26·84 tons) showed comparatively less decline. The boat-seines (303·85 tons) made over one half of the total catch. In 1955 the catch again declined (438·79 tons), the boat-seines having failed again. The line catches showed a phenomenal increase to 142·47 tons contributing about 30% of the total, while the *rampan* catches showed a 50% rise from that of 1952, amounting to 272·82 tons, which is about 50% of the years total catch. In 1956 the catch was almost double (907·38 tons) that of 1955. The *rampan* catch also was almost double (592·33 tons) that of 1955, the line catches had improved to a certain extent (196·37 tons), while the drift net catches (104·84 tons) were about five times more than in the previous year. The boat seines alone had failed. In 1957 the increase in the total catch was maintained. Also this year's *rampan* catches (748·65 tons) increased by 25% over those of 1956, while the line catches (368·05 tons) almost doubled, and the drift net catches

(21·55 tons) showed a reversal to the 1950 figure. The boat-seines had failed again in 1957 (2·32 tons). From the accompanying graph it is seen that the best period of fishing is during the last four months of the year and that there is a decline in the catch in the first five months, while the three months of June, July and August are the worst. During these months the fishing practically comes to a close because of the monsoon.

The annual catch of the different groups of fishes during the six years as well as their percentage of composition is given in Table VI.

It will be seen from Table VI that there was variation in the landings of the different fishes from year to year. Thus in 1950 the first five principal fishes were *Arius* (299·60 tons, 43·96%), *Sciænids* (139·56 tons, 20·46%), sardines (90·83 tons, 13·33%); mackerel (70·57 tons, 10·36%); and *Trichiurus* (16·81 tons, 2·47%) while in 1951 the five principal fishes in order of importance were sardines (305·43 tons 42·00%) mackerel (214·86, tons, 29·55%), *Sciænids* (37·76 tons, 5·19%), elasmobranchs (35·58 tons, 4·89%) and crustacea (21·95 tons, 3·02%). In 1952 the most important fishes were *Sciænids* (248·02 tons 46·38%), sardines (108·24 tons 20·19%), *Arius* (66·67 tons 12·44%), whitebait (41·99 tons 7·83%) and elasmobranchs (21·01 tons 3·92%); in 1952 the mackerel fishery was a failure (15·27 tons, 2·85%) and was sixth in importance. In 1955 the sardines (129·56 tons, 29·52%) dominated the catch followed by the mackerel (103·50 tons, 24·73%) *Arius* (85·24 tons 19·44%), sharks and rays (45·93 tons, 10·47%) and *Carangids* (18·25 tons 4·16%). In 1956 sardines again formed the important fish (203·82 tons, 22·46%) followed by *Sciænids* (148·12 tons 16·33%), while *Arius* was third in importance (145·20 tons 15·99%) followed by mackerel (109·76 tons, 12·10%) and *Carangids* (60·63 tons, 6·68%). In 1957 mackerel (305·94 tons, 26·82%) was the most abundant of the fish landed, followed by the sardines (288·07 tons, 25·25%), *Arius* (275·91 tons, 24·19%), *Sciænids* (115·02 tons, 10·08%) and elasmobranchs (82·40 tons 7·22%). But if the average annual yield of the important fishes is taken into consideration, then he fishes in order of importance were sardines (187·66 tons), *Arius* (147·11 tons), mackerel (137·89 tons), *Sciænids* (115·06 tons) and elasmobranchs (40·88 tons). The whitebait and the crustacea also formed a fairly large percentage of the catch but they are caught in the *rampan* along with other fishes like mackerel and sardine and do not form a fishery by themselves.

Annual and Seasonal Fluctuations in the Major Fisheries

The fishes of economic importance at Malwan are (1) Mackerel, (2) Sardine (3) *Arius-Sciæna*, (4) Elasmobranchs, (5) Seer and (6) Pomfrets. These are dealt with in detail below.

TABLE VI

Fish	1950		1951		1952		1955		1956		1957		Total	Average
	Catch	%	Catch	%	Catch	%	Catch	%	Catch	%	Catch	%		
Mackerel ..	70·57	10·36	214·86	29·55	15·27	2·85	108·50	24·73	109·76	12·10	305·94	26·82	824·90	137·89
Sardines ..	90·83	13·33	305·43	42·00	108·24	20·19	129·56	29·52	203·82	22·46	288·07	25·25	1125·95	187·66
Sciaenids ..	139·56	20·46	37·76	5·19	248·02	46·38	1·87	0·43	148·12	16·33	115·02	10·08	690·95	11·16
Scomberomorus ..	2·25	0·33	18·78	2·58	8·44	1·58	10·31	2·35	28·68	3·16	4·32	0·38	72·78	12·13
Thunnidæ ..	5·72	0·84	0·26	0·04	..	..	9·87	2·25	0·34	0·04	0·79	0·07	16·98	3·39
Clupeoids ..	3·25	0·48	5·57	0·76	2·31	0·43	0·01	..	0·88	0·10	1·80	0·15	13·82	2·29
Whitebait ..	1·18	0·17	12·21	1·68	41·99	7·83	10·69	2·44	25·04	2·76	7·33	0·64	98·44	16·40
Elasmobranchs ..	10·03	1·47	35·58	4·89	21·01	3·92	45·93	10·47	50·32	5·55	82·40	7·22	245·27	40·88
Arius ..	299·60	43·96	10·08	1·39	66·67	12·44	85·24	19·44	145·20	15·99	275·91	24·19	882·70	147·11
Carangids ..	13·86	2·04	19·46	2·68	1·53	0·28	18·25	4·16	60·63	6·68	7·22	0·63	120·95	20·16
Trichiurus ..	16·81	2·47	2·88	0·40	0·18	0·03	0·32	0·07	27·10	2·99	5·86	0·52	53·15	8·86
Stromateus ..	0·92	0·14	5·59	0·77	1·78	0·33	2·20	0·50	7·97	0·88	8·02	0·70	26·48	4·41
Leiognathus and *Lactarius*	4·45	0·65	19·42	2·67	11·17	2·08	4·57	1·05	25·98	2·86	3·95	0·35	69·54	11·60
Perches ..	9·67	1·12	4·08	0·56	0·21	0·04	0·78	0·18	9·70	1·07	5·65	0·50	30·09	5·07
Crustacea ..	5·33	0·78	21·95	3·02	4·54	0·85	2·82	0·64	19·07	2·10	11·98	1·05	65·69	10·95
Miscellaneous ..	7·48	1·10	13·23	1·82	4·09	0·77	7·87	1·78	44·77	4·93	16·50	1·45	93·94	15·65
TOTAL ..	681·51	100·00	727·14	100·00	536·06	100·00	438·79	100·01	907·38	100·00	1140·76	100·00	4431·63	..

Mackerel Fishery.—Mackerel is a very important fish at Malwan and bulk for bulk this fish gives the fisherman the maximum returns. If the mackerel season is good then the fisherman can expect to live through the monsoon with comfort. But if the mackerel fishery fails he has to get into debt during the slack season. At Malwan, as in other places, it is an inshore fishery and is carried on by means of the shore-seine, the *rampan*. The net as mentioned earlier consists of about 100 or at the most 125 pieces and the average catch is about $\frac{1}{2}$ lakh of mackerel. The record catch at Malwan was 2 lakhs. Mackerel is also caught by the gill nets at Malwan. But there are only two gill nets owned and operated by the Malwan fishermen. There is a convention among the fishermen here that the gill nets should not be operated during the months when the *rampans* are operated; hence the operation of these nets is restricted to the months of February–March, that is the end of the mackerel season. The total catch of the mackerel during the six years was 70·57, 214·86, 15·27, 108·50, 109·76 and 305·94 tons respectively. In the first half of 1950 the *ra npan* catches were composed of mainly mackerel, but in the latter half of the year, that is, from October–December, there was no mackerel in the catches which were dominated by the sardines. In 1951 good catches of mackerel were landed till about the end of February but again in March the *rampan* catch was mainly composed of sardines with stray mackerel. In the latter half of the year the catch seemed to be very promising and in October each net landed heavy catches of mackerel; but suddenly in November the fishery failed. Line and drift net fishermen, who went out beyond 5 or 6 miles, reported the presence of mackerel shoale there, but they did not enter the inshore regions. As stated above, gill nets are by convention, barred from operating during the November–February period and there are no boat-seines suitable for the capture of mackerel. Thus a season which started well ended in a failure. In 1952 the season was a total failure. Mackerel were landed in fairly satisfactory quantities in January and February 1955. But the catches declined subsequently till October, and the fishery terminated in November though stray mackerel were landed in December. In 1956 the catches were evenly spread out, fairly good amounts of mackerel being landed in every month except in October when the catch was slightly lower. In 1957 the bulk of the mackerel was landed in the first two months, while in the latter half of the year it was practically a failure.

Sardine Fishery.—The sardines are normally caught at Malwan along with mackerel in the *rampan* nets. It is the general belief of the local fishermen that when the mackerel are in plenty the sardines are scarce and *vice versa*. The analyses of the landings indicate such a relationship in

the respective catches. The inverse relationship in the mackerel and sardine fisheries has been indicated by Nair and Chidambaram (1951). The fishery includes four species of the sardines, namely, *Sardinella longiceps*, *S. fimbriata*, *S. albella* and *Dussumieria hassultii*. Table VII shows the magnitude of landings of these four species during the six years and their percentage composition in each year's total catch.

TABLE VII

	1950	1951	1952	1955	1956	1957	Total
Sardinella longiceps	66·29	1·31	44·50	3·20	43·44	74·23	232·97
S. fimbriata ..	2·86	164·17	59·81	126·83	137·40	231·31	703·88
S. albella ..	21·55	90·69	0·99	..	..	..	113·23
Dussumieria hassultii	0·13	49·26	2·93	0·02	22·98	0·53	75·85
TOTAL ..	90·83	305·43	108·23	129·55	203·82	288·07	1125·93
Per cent. ..	13·33	42·00	20·19	29·52	22·46	25·25	

Of the four species of sardines obtained at Malwan, *S. fimbriata* occurs more abundantly and forms a regular fishery; *S. albella* has not been recorded since 1955; *Dussumieria* makes sporadic appearance once every other year. In 1950 *S. longiceps* and *S. albella* were the most abundant species of the group, while in all the subsequent years *S. fimbriata* dominated the catches. The catches of *S. longiceps* declined to a great extent in 1951 as compared to 1950, increased in 1952, declined in 1955 and seem to be increasing since then. The figures indicate that the catches of the three sardines steadily increased during the years while the *Dussumieria* catches were more or less steady with unusually heavy catches during 1951 and 1956. The period of occurrence of the different species of sardines is shown in Table VIII.

Arius-Sciæna *Fishery*.—The fishery for *Arius* (shengala) and *Sciæna* (ghol) lasts for a very short time, about 15–20 days, intermittently during September and October. During the favourable seasons these fishes are caught in large quantities and the gutting process goes on throughout the night. There are instances of heavy catches, the gutting of which continued the next day

TABLE VIII

	1950	1951	1952
S. longiceps ..	January, November, December	January, March, December	December
S. fimbriata ..	January, May, August	January, March, April, September, October, November, December	January February, April, May, October, November, December
S. albella ..	January, May, August, September, October, December	January, February, March	February
Dussumieria ..	September	January, February, October	February, September
	1955	1956	1957
S. longiceps ..	January	November, December	January, February
S. fimbriata ..	February, March, April, September, October, November, December	January, February, March, July, August, September, November, December	January, February, March, April, May, June, September, October, November, December
S. albella ..	..	..	..
Dussumieria ..	February	February, December	..

till that day's catch came in, when the previous day's catch was disposed of in a tainted condition. On the other hand if the season is a failure, no catch is made, as in 1951. The fishermen go out with the seines on getting news of the presence of the shoals from the drift net or the line fishermen, but operate the net only if the fish are seen in a shoal or if the fishermen think they have a fair chance of catching the shoals; otherwise they do not operate the net but return to the shore. Generally the bigger *rampan* boats are used in the operation. The fishery was a very successful one during 1950, the catch amounting to 253·88 tons of *Arius* and 96·84 tons of *Sciæna*. It was reported that a bumper catch of 51 tons was landed during the interval during two consecutive observations made at this centre. The fishery extended up to October in 1950 and this was the case in all the six major fisheries which appeared late by a month or so during the year. In 1950 this fishery was valued at Rs. 15,000 approximately. The fishery was a total failure in 1951. However, 10·08 tons of *Arius* and 37·76 tons of *Sciæna* were caught in the other types of gear operated during the year. In 1952 this fishery alone

helped the fishermen to make a living for the year; bringing them Rs. 8,000–10,000. During this year the boat-seines caught 244·78 tons of *Sciæna* and 66·67 tons of *Arius*. In the subsequent years the fishery has been declining and in 1955 this fishery again proved a failure. In 1956 and 1957 small quantities of these two fishes, amounting to 9·88 tons and 2·31 tons, were landed valued at Rs. 5,000 and Rs. 1,500 approximately.

Elasmobranch Fishery.—Shark fishery is carried on throughout the year except during the monsoon months of June–August. Invariably dug-out canoes are used for the purpose and they go out to a distance of 10–12 miles from the shore. The implements used are the hooks and lines with about 100 hooks to a line. Hooks of size No. 0, 1, 2, 3, 4 and 5 and occasionally home-made hooks of 6″ size are generally used. Of these No. 0, 1 and 2 hooks are used during the months of November–February when the boats go to greater depths and No. 3, 4, and 5 are used during the other months of the year. Eels, *Loligo*, small *Arius* and sardines are used as bait. The lines are baited and usually left in the sea overnight and the catch collected the next day, the line rebaited and left again. The catch is generally composed of *Carcharhinus*, *Scoliodon*, *Sphyrna*, *Pastinachus*, etc., but sometimes stray specimens of *Arius*, *Sciæna*, *Euthinnus*, *Muræsox*, etc., have also been landed. The catch landed by the line boats amounted to 8·62 tons in 1950, to 34·68 tons in 1951, but declined to 26·48 tons in 1952. But in subsequent years the catch has increased and in 1955 the total landings amounted to 142·47 tons, while in 1956 and 1957 the catches were 196·37 tons and 368·05 tons respectively. Of this the elasmobranchs were 10·03, 35·58, 21·01, 45·93, 50·32 and 82·40 tons in the respective years. The rest of the catch was composed of *Arius*, *Euthinnus*, *Chorinemus*, etc. Heavy catches of *Chorinemus* and *Arius* were observed specially in 1956 and 1957. The value of the catch for these years was estimated to be Rs. 17,000, Rs. 5,000, Rs. 3,200, Rs. 25,000, Rs. 40,000 and Rs. 70,000 respectively.

Seer-fish Fishery.—Seer-fishing is carried out on a large scale at Malwan during February–March and October–December. The latter period is considered the best season for this fishery and during this period seer of all sizes are caught by using the different varieties of drift nets such as the *surmai jal*, *kandali*, *wawari* and *dhangad*. The first three types of nets are operated from the canoes. These go out at night at about 11 o'clock and return at about 7–9 o'clock in the morning the next day. The catches are generally better during the darker half of the month. The *dhangad* is operated from the smaller of the out-rigger boats which fish usually during the daytime, going at about 8–9 A.M. and returning between 3–6 P.M. These boats usually land *Scomberomorus commersonii* in large quantities. In addition

to the local boats, boats from as far north as Jaigad and Jaithapur come and camp at Malwan during the season and operate from there. *Scomberomorous guttatus*, *S. kuhlii*, *S. commersonii* and *S. leniolatum* constitute the fishery. Of these *S. commersonii* is the biggest in size, the maximum recorded being 4′ 6″ weighing 17·24 kg. It is interesting to note that only young ones of *S. guttatus* are caught during the other months of the year. The seer-fish catch has been estimated at 2·25 tons (0·33%) in 1950, 18·78 tons (2·58%) in 1951, 8·44 tons (1·58%) in 1952, 10·31 tons (2·35%) in 1955, 28·68 tons (3·16%) in 1956 and 4·32 tons (0·38%) in 1957. The total returns from these catches to the fishermen during the respective years were estimated at Rs. 800, Rs. 12,000, Rs. 8,000, Rs. 7,000, Rs. 20,000, Rs. 3,200. Other fishes such as the *Hilsa*, *Carcharhinus*, *Arius*, *Parastromateus*, *Chirocentrus*, *Sciæna*, *Chorinemus*, *Rachicentron* and *Histiophorus* are usually caught in the drift nets.

Pomfret Fishery.—The pomfret fishery coincides with that of the seer, and pomfrets are caught in the months of February–April and September–November. The boats employed are the dug-out canoes and the net used for the pomfret when it is abundant, is invariably the *saranga jal*. But the usual practice is not to take a net made up of one type of net only but an *aut* which will have a few pieces of all types of drift nets mentioned earlier. The *saranga jal* is used exclusively in the pomfret fishery for only a few days in the year. *Parastromateus niger* forms almost the only species contributing to this fishery, while *Pampus argenteus* is sometimes caught in the *rampan*, or a few may be landed by the drift nets. In 1950 the *Parastromateus* catch amounted to 0·92 tons (0·14%), in 1951 it was 5·59 tons (0·77%) but the next year it declined to only 1·78 tons (0·33%). It has shown a rise in the subsequent years from 2·20 tons (0·50%) in 1955 to 7·97 tons (0·88%) in 1956 and to 8·02 tons (0·70%) in 1957. The estimated rough value was computed to be about Rs. 800, Rs. 1,750, Rs. 5,600 and Rs. 5,000 during the different years. Pomfrets are the prized fish in this region and fetch Rs. 0·75–1·50 per fish depending upon the size and the availability. Almost all of the pomfret catch, unlike the other fishes, is consumed in the fresh condition.

Disposal of Fish

About 40% of the fish caught at Malwan is consumed fresh, the rest being cured or converted into manure. Of the latter (60% of the total caught) 30–40% is cured by the wet process, another 40–50% by the dry process and the remaining 30–10% is beach-dried for manure. Since the different methods of curing have been described in detail by Kalyani (1954)

and others they are not given here as the same system is practised at Malwan. Wet curing is practised in the case of mackerel and seer; only about 10% of the sardine catch, especially *S. fimbriata*, is consumed fresh, while the rest is beach-dried for manurial purposes. *Sciæna* and *Arius* are cured by the dry process and almost the whole of the catch is cured. Sharks are dry-cured to the extent of about 90% of the catch. As there is a great demand for *Parastromateus* in the fresh condition, during the non-peak period the whole of the catch is sold as fresh fish, while in the peak period hardly 20–25% is cured. About 60% of the mackerel is cured while the remaining 40% is sold fresh. The mackerel is esteemed as a food fish by the people along the entire Konkan coast and its availability in large quantities satisfies the needs of a large portion of the population. Prior to 1937 there were no carrier launches and the whole of the catch had to be disposed of locally. Since 1937, however, carrier launches have been introduced and iced mackerel transported to Bombay. Some quantity is sent in trucks, without using any ice, to places within a distance of twenty miles, and small quantities of iced fish are sent to places like Belgaum and Kolhapur. The cured fish, especially the wet cured, is sent to Ratnagiri in country crafts, from where it goes to the Kolaba District and to the interior of the Ratnagiri District. The dry-cured fish is transported in appreciable quantities to places in the interior like Kolhapur and Belgaum and some dry fish is shipped to Bombay from where it is reported to be exported to Ceylon. Almost the whole of the sardine catch is beach-dried and converted into manure. The sardines are taken in launches to Bombay only when the mackerel catch is poor and the sardines are available in plenty. The beach dried sardines are used as manure for cocoanut palms locally and a major portion of it is sent to Bombay from where it is said to be shipped to Europe. The whole of the *Arius-Sciæna* catch is dry-cured after gutting and the *Arius* is almost always beheaded before curing. A small quantity of the product is sold in the ghat areas and beyond, while the greater portion is sent to Bombay. The maws are also shipped to Bombay from where, it is said, they are shipped to Europe. The shark is not valued as a fresh fish and only when there is a scarcity of other fish it is brought to the market. It is not sent up-ghats as the market in these areas is controlled by Muslims, who as a rule do not eat sharks, not considering it a fish because of the absence of visible scales and its viviparity. Because of these reasons almost the whole of the catch is dry-cured. This cured product is in demand along the coast during the monsoon months when there is no fresh fish available and the cost of fresh fish is high. The price of fish fresh and cured, varies greatly depending upon the quantity and the type of fish available. Table IX gives a rough idea of the fluctuations in the price.

TABLE IX

Name of fish	Price of fresh fish		Price of cured fish	
	Wholesale	Retail	Wholesale	Retail
	Rs.	Rs.	Rs.	Rs.
Mackerel ..	30–40/1,000	60–150/Re.	40–50/1,000	2/100
Arius ..	8–50/100	10–75/100	15–70/100	0·25–1/each
Sciæna ..	15–25/100	20–30/1,000	30–45/100	0·75–1/each
Scomberomorus ..	4–6/25 lb.	8–15/25 lb.	5–7/25 lb.	6 each
Parastromateus ..	1–1·75/each	1·50–2/each	200–300/100	2–3 each
Sharks ..	0·50–3/each	0·75–4/each	75–80/100	1–2 each

SOCIO-ECONOMICS

The soil around Malwan is laterite and vegetables cannot be grown on a large scale and the imported vegetables are beyond the means of the major portion of the population, of 20,000. The population has, therefore, to depend almost entirely on the fish and hence the *per capita* consumption is quite high and is computed at about 45·4 kg. a year. As already stated the fishermen's income is either from the mackerel or from the *Arius-Sciæna* catch. In 1950 the mackerel catch though not so high, yielded good returns to the fishermen. The mackerel catches had not come up to the level expected in the south and consequently the Malwan fishermen got higher prices for their catch. The *Arius-Sciæna* catch was also tolerably good and thus the fishermen earned about Rs. 500 each. In 1951 the mackerel catch was better than that in 1950, but the catch was better still in the south and hence the price which the fishermen got was not favourable. The boat-seine catches had failed completely and the fishermen earned no income from this source. Hence their income dropped to the low figure of Rs. 350. In 1952 the condition of the fishermen was very bad; the mackerel fishery had failed completely nor were there any catches of sardines, but the good boat-seine catches helped them to earn about Rs. 175 per head in this year. In 1955 the same conditions were repeated but as the total catch was somewhat lower than that of 1952 the income could be said to be about the same as that of 1952. In 1956 and 1957 the catch of the commercially important

fishes as well as the others was exceedingly good and the fishermen earned about Rs. 600–800 in these years. Most of the fishermen of Malwan have no subsidiary occupation; and fishing is the only source of their income.

It is estimated that a *rampan* net costs about Rs. 13,000 and the *rampan* boat about Rs. 1,500. Each *rampan* boat requires two smaller boats for miscellaneous work. Each of these boats costs about Rs. 700. Thus each *rampan* unit costs about Rs. 15,000-16,000. Among the drift nets, a *surmai jal* costs about Rs. 25 per piece and *wawari* about Rs. 22. The boat-seine costs about Rs. 2,000 a net, and the lines cost at the rate of Rs. 40 per line of 40 hooks. Based on the price of boats and nets mentioned above, the amount invested in the fishing industry in Malwan aggregates between Rs. 7,95,000 and Rs. 8,50,000. The income from this investment is uncertain; if the season is good then the fisherman earns about Rs. 500–600 in a year; otherwise the income may be as low as Rs. 175 in a year.

Trend of Fisheries and Catch per Unit

It will be seen from Tables III and IV that the catches obtained from the different gears varies from year to year. It is therefore necessary to examine if such variations are due to any changes is in effort put in or due to other causes. Table X gives the figures of total catch and the catch per fishing unit for the four main types of gear.

Table X

Rampan

Year	Average No. of units operated	Total catch	Catch/unit
1950	161·36	6,54,662	4058·15
1951	337·38	14,48,518	4293·43
1952	225·55	4,28,288	1898·86
1955	269·88	6,01,462	2228·63
1956	997·41	13,05,852	1309·23
1957	850·71	16,50,476	1940·11

Drift net

Year	Average No. of units operated	Total catch	Catch/unit
1950	855·77	46,166	53·95
1951	1320·70	62,070	46·99
1952	1038·56	25,289	24·34
1955	1702·22	43,948	25·81
1956	2049·10	2,31,145	112·80
1957	3113·95	47,150	15·26

Boat-seine

Year	Average No. of units operated	Total catch	Catch/unit
1950	61·07	8,88,176	14543·57
1951	49·50	..	..
1952	119·79	6,69,894	5592·23
1955	..	..	..
1956	71·90	21,772	302·80
1957	46·50	5,107	109·83

Line

Year	Average No. of units operated	Total catch	Catch/unit
1950	100·86	18,995	188·33
1951	1357·50	76,473	56·34
1952	1334·03	59,396	44·52
1955	3585·41	3,14,092	87·60
1956	6050·82	4,32,924	71·55
1957	9587·65	8,11,417	84·63

In the case of the *rampan* the magnitude of effort is at its lowest in 1950, increases to a certain extent in 1951, but declines in 1952 and 1955, and thereafter shows a considerable increase. A more or less similar picture is presented in the case of the drift net. The annual catch in respect of these nets also follows a similar pattern of fluctuations, that is, with increasing effort increasing catches are obtained. But the trend in the catch-per-unit is quite different. In the case of the *rampan* where the effort has increased more than five times, the catch-per-unit has declined by nearly half. The increase in effort in the drift net during the corresponding period has been nearly four-fold but the catch-per-unit has been reduced to one-third. In the case of the boat-seine there has been variation in the magnitude of annual catch and effort. But the catch-per-unit has considerably declined from 1950–1957. In the case of the line there is considerable variation. The effort has consistently increased from year to year, the total catch also increased along these years, but the catch-per-unit is found at its highest in 1950, declines till 1952, rises again in 1955, to decline in 1956 then rise in 1957. From this no conclusion can be drawn.

In general, however, it must be said that at Malwan there is a decline in the catch-per-unit since 1950. As already stated, the catch-per-unit in the case of the line fluctuates greatly to allow drawing of any conclusions, and it must be noted that comparatively few fishermen own and operate lines. The majority of them work with *rampan* nets, drift nets or boat-seines. Hence the decline in the catch-per-unit, which has been occurring in all these three modes of fishing, affords genuine cause for concern. It becomes necessary to try to find out the causes of such decline. With increasing effort, the catch-per-unit always goes down but not to the extent noticed at Malwan. The cause of the decline may be due to the variation in the availability of the fish population. However a detailed investigation appears to be necessary before the real causes can be determined.

Summary

(1) Malwan, the taluk headquarters in the Ratnagiri District, is one of the major fishing centres on the Konkan Coast. Canoes and out-riggers are used for fishing and the gear employed are the shore-seine, boat-seine, drift net, gill net and line.

(2) *Rampans* are operated during September–May. Drift nets of various types are operated during the fishing season depending upon the type of fishes. Gill nets are operated in March and lines from September to May. The catch has been estimated to be 681·51, 727·14, 536·06, 438·79, 907·38

and 1140·77 metric tons for the years 1950, 195 . 952, 1955 956 '957 respectively.

(3) The major fisheries contributing to the fish production are mackerel, sardines, *Arius*, *Sciæna*, elasmobranchs, seer and pomfrets. The fluctuations of these fishes during the six years of study are discussed in detail.

(4) About 40% of the catch is consumed fresh, of the remainder of the catch 30–40% is cured by wet process, 40-50% by dry process and the remaining 30–10% is beach-dried for use as manure.

(5) Fresh fish is sent in trucks to places in the interior across the ghats, such as Belgaum and Kolhapur and by carrier launches to Bombay. The cured fish goes to the interior and to Bombay for export.

(6) The investment in the fish trade is estimated at Rs. 8,00,000–8,50,000 and the return at Rs. 400 per fisherman in an average season.

(7) The fishery by-products are processed in a crude form and sent to Bombay for export.

(8) The catch-per-unit has been falling steadily in respect of all the gears operated excepting only the line. The fall in the case of the *rampan* is from 4058·15–1940·11. In drift nets it is from 53·95–15·26 and in the boat-seines it is from 14543·57–109·83. In the case of the lines it varies too much to draw any conclusions. Investigations to determine the causes for this falling trend in the fishery appears to be necessary.

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INDIAN TUNAS—A PRELIMINARY REVIEW, WITH A KEY FOR THEIR IDENTIFICATION

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Introduction

Until recently only scant attention has been paid to the study of Scombroid fishes in general and tunas in particular occurring in the Indian Seas. That tunas form an untapped resource awaiting exploitation needs hardly any stress. Year after year, Japanese fishing vessels operating in the high seas off Indian coast and other parts of the Indian Ocean reap rich harvests as will be evident from reports of catch statistics published by them (Average years fishing condition of tuna long line fisheries by the Nankai Regional Fisheries Laboratory and other publications emenating from Japan).

Due to the spade-work done by Kishinouye (1923), Serventy (1941), Godsil and Byers (1944), Rosa (1950), Fraser-Brunner (1951), Godsil (1954) and others we have a fair idea of the species of tunas occurring in the Indo-Pacific. However, the lacuna in our knowledge of the species of tunas occurring along the Indian coast is rather appalling. Day (1878) records the undermentioned four species.

Day's species	Up-to-date Nomenclature
Thynnus thunnina Cuvier and Valenciennes	= *Euthynnus affinis affinis* (Cantor)
Thynnus pelamys Linnaeus	= *Katsuwonus pelamis* (Linnaeus)
Thynnus macropterus Temminck and Schlegel	= *Neothunnus macropterus* (Temminck and Schlegel)
Pelamis chilensis Cuvier and Valenciennes	= *Sarda orientalis* (Temminck and Schlegel)

From Ceylon waters Deraniyagala (1952) lists in addition *Thunnus (Kishinoella) tonggol* (Bleeker) [= *Kishinoella tonggol* (Bleeker)], while he does not mention *Sarda orientalis* as occurring there. In addition to the four species given by Deraniyagala, Munro (1955) mentions an additional

species, *Auxis thazard* (Lacépède). The 1953 *Proceedings of the Indo-Pacific Fisheries Council* contains a brief reference to *Euthynnus affinis* and *Thynnus tonggol* as constituting the tuna fishery of India. There is no mention of any species in a brief note on the tuna fisheries of Bombay by Deodhar (1953) in the same publication. Smith (1949) records *A. thazard* (Lacépède), *Euthynnus pelamis* (Linnaeus); *Euthynnus alletteratus* (Rafinesque), *Thunnus thynnus* (Linnaeus), *Sarda chilensis* (Cuvier and Valenciennes), *Germo itosibi* (Jordan and Evermann), *Germo albacora* (Lowe), and *Germo alalunga* (Bonnaterre) from South African waters of both the Indian Ocean and the Atlantic, while de Beaufort (1951) describes *Euthynnus pelamis* (Linnaeus), *E. alletteratus affinis* (Cantor), *Thunnus sibi* (Schlegel), *T. macropterus* (Schlegel), *T. tonggol* (Bleeker), and *Auxis thazard* (Lacépède) from the Indo-Australian Archipelago.

Jones (1958 *a*) recorded two species of Frigate mackerels *Auxis thazard*, and *A. tapeinosoma* from Indian waters and Jones (1958 *b*) and Jones and Kumaran (1959) have reported on the Tuna Fishery of Minicoy Island of the Laccadive Archipelago, therein also recording *Auxis thazard*, *Neothunnus macropterus*, and *Katsuwonus pelamis*. In the series entitled "Eggs, larvæ and juveniles of fishes from Indian waters", *Katsuwonus pelamis*, *Neothunnus macropterus*, *Euthynnus affinis*, *Auxis* spp. and *Sarda orientalis*, have received attention (Jones 1959 and 1960 *a* and *b*). While recording seven scombroid fishes including *Euthynnus affinis* and *Gymnosarda unicolor* (Rüppell) from the Andaman-Nicobar waters (Jones, Silas and Dawson, 1960) attention was also drawn to the fact that more intensive surveys would show the presence of other species of scombroids in those waters. Japanese works already mentioned indicate the occurrence of *Thunnus germo* (Lacépède), *T. orientalis* (Temminck and Schlegel), *Parathunnus mebachi* (Kishinouye), and *Neothunnus macropterus* (Temminck and Schlegel) in the Andaman-Nicobar waters of the Indian Seas.*

Herein we are able to record 13 species and subspecies of tunas from Indian Seas. Of these we have been able to examine material of ten and of the remaining, *Cybiosarda elegans* Whitely known also from Western Australia and is likely to occur in other parts of the Indian Ocean is included. *Thunnus thynnus orientalis* and *T. alalunga* are based on Japanese records.

The more one looks into the systematics of the tunas, the greater will one find the similarities at the species level between those occurring in the

* Fish collections made during February–March 1961 from the Andaman Islands by Messrs. K. V. Rao and G. Luther of this Institute has added one more species of tuna., *Kishinoella tonggol* (Bleeker), to the list.

Indo-Pacific on the one hand and in the Atlantic Ocean on the other hand. Hence the nomenclature used here is the result of a preliminary assessment of the species occurring in these oceans; priority being given to the earlier names proposed.

Body Dimensions Used in Describing Tunas

Marr and Schaefer (1949) have defined the body dimensions used for describing tunas and to facilitate easy reference we give these characters below and have also indicated them in the accompanying figure (Fig. 1). Characters which should not be missed are marked thus*.

1. **Total length.*—Tip of snout to caudal fork depressing small fleshy flap extending posteriorly to indicate end of hypural.
2. **Head length.*—Tip of snout to most posterior point on sub-opercle depressing fleshy margin extending posteriorly.
3. **Snout to insertion of first dorsal.*
4. **Snout to insertion of second dorsal.*
5. **Snout to insertion of anal.*
6. **Snout to insertion of ventral.*
7. **Greatest depth.*—Greatest vertical distance between dorsal and ventral contours with first dorsal depressed in its slot and the exact position indicated with reference to the number of the dorsal spine, the insertion of which is nearest the upper end of the vertical.
8. **Length of pectoral.*—From the point of intersection of the dorsal margin of the pectoral with the body to the tip of the fin.
9. *Pectoral insertion to insertion of first dorsal.*
10. *Length base first dorsal.*—Insertion of first dorsal to insertion of second dorsal.
11. *Length base second dorsal.*—Insertion of second dorsal to intersection of posterior margin of it with body contour including any attached finlet.
12. *Caudal spread.*—Distance between dorso-posterior and ventro-posterior extremities of caudal fin.
13. *Length longest dorsal spine.*—Longest spine of first dorsal.
14. *Length first dorsal spine.*—First spine of first dorsal.
15. **Length second dorsal.*—From anterior insertion to tip with fin in normal position.

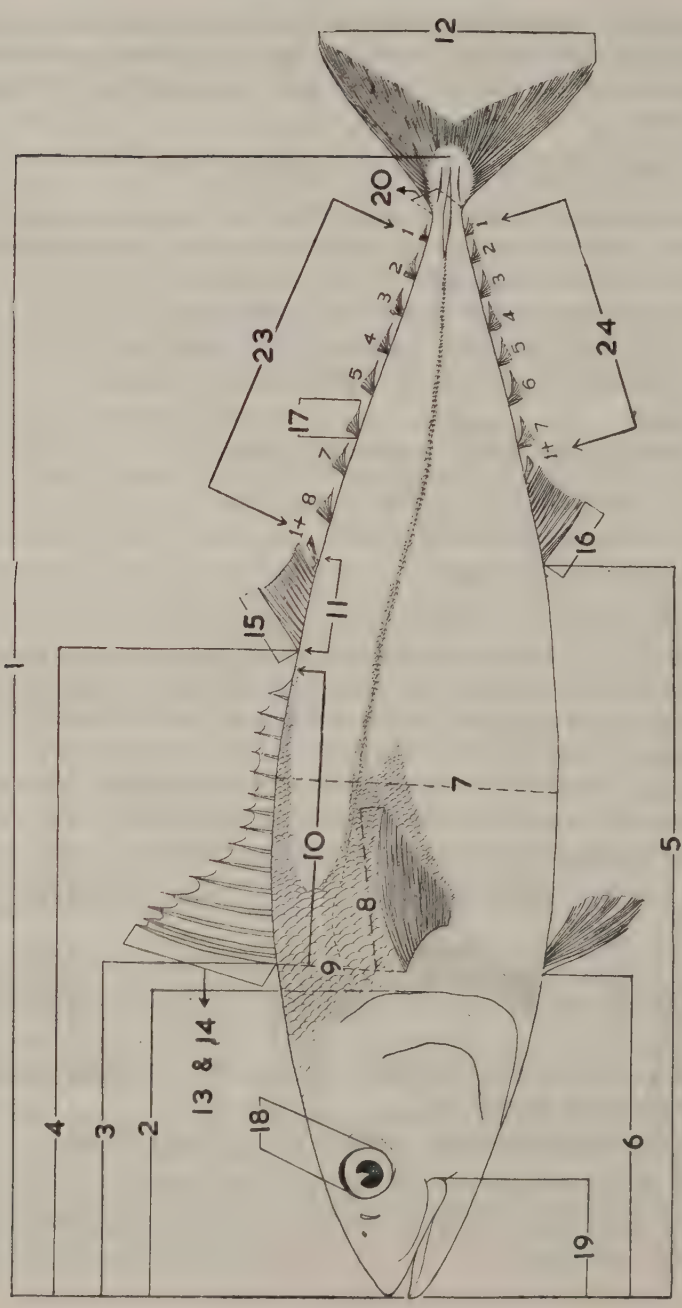

FIG. 1. Schematic drawing of tuna showing methodology to be used in taking body proportions. The numbers in the figure correspond with those given under the section "Body dimensions used in describing tunas" (Nos. 21, 22 and 25 are not indicated in the figure).

16. **Length anal.*—From anterior insertion to tip with fin in normal position.

17. *Length longest dorsal finlet.*

18. **Diameter of iris.*—Greatest diameter measured to margin of yellow iris and adjoining black tissue. Generally oblique to median line of body.

19. **Length maxillary.*—Tip of snout to posterior end of maxillary.

20. *Least depth caudal peduncle.*—Least vertical distance behind finlet but ahead of base of caudal.

21. *Greatest width caudal peduncle at keels.*

22. **Number of first dorsal spines.*

23. **Number of dorsal finlets.*—Most posterior one is counted as No. 1 and the one nearest second dorsal is the last. In case of attached finlet the latter is indicated as +1 (*e.g.*, 8+1).

24. **Number of anal finlets.*—Same procedure as above.

25. **Number of gill rakers.*—Refers to number of gill rakers on the outer side of the outermost gill arch, those of the upper limb and lower limb being indicated separately (*e.g.*, 7+12).

In addition to these, the undermentioned characters should also be noted whenever possible.

**Weight.*

**Sex.*—"Determined by inspection. Very immature males and females may be difficult to distinguish. Ovaries, which are tubular, may often roll between the fingers, while testes, which are solid, will turn over. The testes of ripening or ripe males are enlarged, solid, white bodies, not round in cross-section. The ovaries of ripening or ripe females are enlarged, turgid, pink or yellow-orange bodies, round in cross-section. Ova may often be distinguishable with the naked eye. The testes of spawned-out (*and recovering*) males are less turgid, tougher and pinker than those not spawned, and are difficult or impossible to distinguish from maturing testes in early stages. The ovaries of spawned-out females are hollow, more or less flabby, sac-like tubes" (Marr and Schaefer, 1948). (*The portion in parenthesis ours*).

**Liver.*—Whether the surface of the liver is plain or only striated along the margin or the entire surface (Fig. 2).

KEY TO THE SPECIES OF INDIAN TUNAS[1, 2]

1 *a*. First and second dorsal fins widely separated by distance exceeding length of base of first dorsal.....2

1 *b*. First and second dorsal fins contiguous or separated by only a narrow interspace not exceeding diameter of orbit.....3

2 *a*. Corselet scales abruptly taper immediately below end of first dorsal and continue as a very narrow band having not more than four rows of scales in a line below second dorsal; gill rakers on lower limb about 40.

.....*Auxis thazard* (Lacépède)

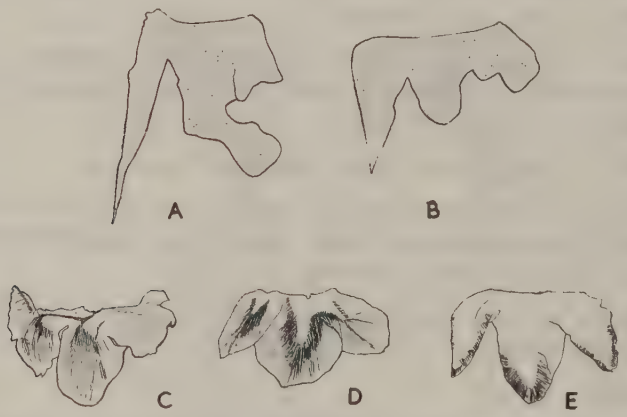

FIG. 2. Liver of five species and subspecies of tunas showing the plain and striated conditions. A. Oceanic skipjack, *Katsuwonus pelamis*; B. Yellowfin tuna *Neothunnus macropterus*; C. Albacore *Thunnus alalunga*; D. Oriental bluefin tuna *Thunnus thynnus orientalis*; E. Big-eyed tuna *Parathunnus obseus mebachi* (after Godsil and Byers, 1944).

2 *b*. Corselet scales gradually taper behind first dorsal and continue as a wide band with 7–12 rows of scales in a line below seventh dorsal finlet; gill rakers on lower limb about 45–46.

.....*Auxis thynnoides* Bleeker

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[1] Sette (1952: *Proc. Indo-Pacific Fisher. Counc.*, 4th Meeting, Sec. 1: 65-67) in the Report for 1952 of the Sub-Committee on Tuna, lists also *Grammatorcynus bicarinatus* (Quoy and Gaimard) under 'Available tuna morphometric data'. However, for reasons given below (p. 377), we have not included this species in this review on Indian Tunas. The presence of a second decurved lateral line commencing from a point above mid-length of pectoral and travelling along the lower half of the abdomen to the caudal keel where it becomes confluent with the upper lateral line should help in easily distinguishing this species from all the tunas, though this has been recorded from Indian waters (Jones, Silas and Dawson, 1960).

[2] Body proportions given apply to late juveniles and adults.

3 *a*. Distance from tip of snout to end of maxilla 50% or more of head length; end of maxilla surpasses vertical below middle of orbit. 4

3 *b*. Distance from tip of snout to end of maxilla considerably less than 50% of head length; end of maxilla does not surpass vertical below middle of orbit.....6

4 *a*. Vomer with villiform teeth; dorsal and anal finlets 9 or 10/7 or 8. .....*Cybiosarda elegans* Whitely

4 *b*. Vomer edentulous; dorsal and anal finlets 6–8/5 or 6.....5

5 *a*. Dorsal with 18 or 19 spines; end of maxilla surpassing vertical below posterior border of orbit; 6–9 horizontal dark stripes on upper half of body appear as short broken bars in juveniles. .....*Sarda orientalis* (Temminck and Schlegal)

5 *b*. Dorsal with 14 spines; end of maxilla reaching to vertical below posterior third of orbit; No dark stripes on body. .....*Gymnosarda unicolor* (Rüppell)

6 *a*. Body completely scaled; those of corselet and lateral line usually larger 7

6 *b*. Body naked except for corselet and lateral line.....12

7 *a*. Anterior insertion of second dorsal nearer to posterior end of caudal keel than to posterior margin of orbit.....8

7 *b*. Anterior insertion of second dorsal nearer posterior margin of orbit than to posterior end of caudal keel.....10

8 *a*. Pectoral short, not exceeding head length excluding snout and falling short of vertical below anterior insertion of second dorsal by distance equalling its own length; pre-operculum distinctly rounded along posterior margin. .....*Thunnus thynnus orientalis* (Temminck and Schlegel)

8 *b*. Pectoral elongate, one to one and a half times length of head and extends to or surpasses vertical below anterior insertion of second dorsal; preoperculum more or less angular at lower posterior margin.....9

9 *a*. Gill rakers on lower limb 19–21; surface of liver markedly striated; vent rounded; distance between tip of pectoral and end of caudal keel much less than head length. .....*Thunnus alalunga* (Bonnaterre)

9 *b*. Gill rakers on lower limb 16–18; liver marked with faint striations on margin only; vent elliptical; distance between tip of pectoral fin and end of caudal keel greater than head length.

.....*Parathunnus obseus mebachi* (Kishinouye)

10 *a*. Gill rakers not more than 18 on lower limb, generally 15 or 16; air-bladder absent; finlets with hardly any yellow, being predominantly dusky.

.....*Kishinoella tonggol* (Bleeker)

10 *b*. Gill rakers 19–22 on lower limb; air-bladder present; finlets lemon yellow with narrow dusky edging.....11

11 *a*. Pectoral surpassing vertical below anterior insertion of second dorsal; anal and second dorsal not elongate and shorter than pectoral.

.....*Neothunnus macropterus* (Temminck and Schlegel)

11 *b*. Pectoral falls short of vertical below anterior insertion of second dorsal; anal and second dorsal greatly elongate, being considerably longer than pectoral.

.....*Neothunnus itosibi* (Jordan and Evermann)

12 *a*. Four or more dark conspicuous longitudinal stripes on lower half of body; gill rakers 15 or 16 + 36–40.

.....*Katsuwonus pelamis* (Linnaeus)

12 *b*. No dark stripes on lower half of body, instead a few conspicuous black spots on side of body behind corselet below pectoral base; gill rakers 7–10 + 22–25.

.....*Euthynnus affinis affinis* (Cantor)

Notes on the Species

Family: SCOMBRIDÆ

We recognise the family Scombridæ as defined by Regan (1909) and on the basis of osteological and other characters given by Starks (1910), Kishinouye (1923), Godsil and Byers (1944), Fraser-Brunner (1950), Rivas (1951) and de Sylva (1955), the following subfamily groupings are adopted.

Subfamily Scombrinæ .. (*Scomber* Linnaeus; *Pneumatophorus* Jordan and Gilbert; *Rastrelliger* Jordan and Starks; and *Grammatorcynus* Gill).

Subfamily Gasterochismatinæ (*Gasterochisma* Richardson).

Subfamily Thunninæ .. (*Thunnus* South; *Parathunnus* Kishinouye; *Neothunnus* Kishinouye; *Katsuwonus*

Kishinouye; *Euthynnus* Lutken; *Kishinoella* Jordan and Hubbs; *Allothunnus* Serventy; *Orcynopsis* Gill; *Auxis* Cuvier; *Sarda* Cuvier; *Gymnosarda* Gill; and *Cybiosarda* Whitely).

Subfamily Scomberomorinæ (*Scomberomorus* Lacépède; *Cybium* Cuvier; *Indocybium* Munro; and *Acanthocybium* Gill).

Osteological characters indicate the genus *Grammatorcynus* Gill to be more closely allied to the Scombrinæ than to the Thunninæ. We also feel that the proper place in the System of *Auxis*, *Sarda*, *Gymnosarda* and *Cybiosarda* is nearer to the subfamily Thunninæ than to the Scombrinæ or Scombromorinæ. Of the genera listed under the subfamilies only *Allothunnus* and *Orcynopsis* do not occur in the Indian region while the subfamily Gastrochismatinæ is not represented in the Indian Seas. The genera and species are dealt with below in the order in which they appear in the Key to the identification of the species.

Subfamily: Thunninæ

Genus: *AUXIS* Cuvier

Auxis thazard (Lacépède)

(Fig. 3)

FIG. 3. *Auxis thazard* (Lacépède) (After Jones, 1958).

Scomber thazard Lacépède, 1802. *Historie Naturelle Poissons*, **3**: 9.

SYNONYMY.—For detailed synonyms reference is invited to Fraser-Brunner (1950), de Beaufort (1951), Herre (1953) and Jones (1958), with one reservation. The name *Auxis thynnoides* should be substituted for *A. tapeinosoma* where the latter is considered valid, for the typical *A. tapeinosoma* is a synonym of *A. thazard*.

POPULAR NAME.—Short corseletted frigate mackerel.

OCCURRENCE IN INDIAN WATERS.—From Ratnagiri southwards along the west coast; Gulf of Mannar; and Minicoy. Material has been examined from various centres along this range.

GENERAL DISTRIBUTION.—Indo-Pacific and Atlantic.

Auxis thynnoides Bleeker

(Fig. 4)

Auxis thynnoides Bleeker, 1855. *Nat. Tijdschr. Ned. Indie*, **8**: 301.

POPULAR NAME.—Long corseletted frigate mackerel.

FIG. 4. *Auxis thynnoides* Bleeker (after Jones, 1958—given as *A. tapeinosoma*).

REMARKS.—Fraser-Brunner (1950) drew attention to specimens of *A. thazard* from Celebes, Ambonia and Japan having "a slightly longer preorbital part of the head" representing a local subspecies—*tapeinosoma* of which *A. hira* Kishinouye from Japan was considered a synonymy. As already mentioned, Jones (1958 *a*) recorded *A. tapeinosoma* along with *A. thazard* from Indian waters. Recently Mutsumoto (1959) has given sufficient valid reasons for considering *A. tapeinosoma* a synonym of *A. thazard*, while recognising Bleeker's *A. thynnoides* as a good species. The correction that *A. tapeinosoma* Jones (*nec* Bleeker) refers to *A. thynnoides* Bleeker is made here.

OCCURRENCE IN INDIAN WATERS.—Malpe, Calicut and southwards along the West Coast and the Gulf of Mannar. Material has been examined from Malpe, Calicut, Vizhingam, Colachel, and Tuticorin.

GENERAL DISTRIBUTION.—Indo-Pacific.

Genus: *CYBIOSARDA* Whitely

Cybiosarda elegans Whitely

(Fig. 5)

Cybiosarda elegans Whitely, 1935. *Rec. Australian Mus.*, **19**: 4.

POPULAR NAME.—Leaping bonito.

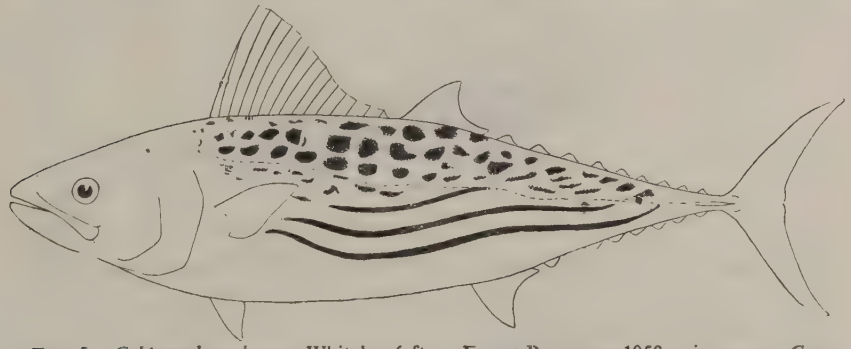

FIG. 5. *Cybiosarda elegans* Whitely (after Fraser-Brunner, 1950—given as *Gymnosarda elegans*).

REMARKS.—Serventy (1941) gives the colour of this species as being a "combination of spots and broken bars above and continuous longitudinal lines below, dark on an iridescent greenish-blue background. First dorsal .....is strikingly parti-coloured, being jet black in front and pearly-white behind". It is likely that in large adults the colour may be much subdued.

C. elegans is said to attain over 41 cm. and weigh about one kilogram.

GENERAL DISTRIBUTION.—This little known species has been recorded along the Australian Coast on the eastern side as far south as Sidney and on the western coast as far south as Fremantle. It is one of the species to be looked for, especially in the Indonesian waters as well as the Andaman Sea. In view of this, the species is included here to facilitate its identification by anyone coming across it from the Indian Seas.

Genus: *SARDA* Cuvier

Sarda orientalis (Temminck and Schlegel)

(Fig. 6 *a*, *b*)

Pelamys orientalis Temminck and Schlegel, 1850. *Faun. Japonic. Pisces*: 90,

SYNONYMY.—Reference may be made to Fraser-Brunner (1950), Rivas (1951), and Herre (1953).

POPULAR NAME.—Oriental bonito.

REMARKS.—Jones (1960 *b*) has shown the variations in the colour pattern in the juveniles of this species. Figure 6 *a* shows a specimen about 245 mm. from Vizhingam in which the longitudinal lateral bands are still interrupted but in adults these become continuous (Fig. 6 *b* after Fraser-Brunner).

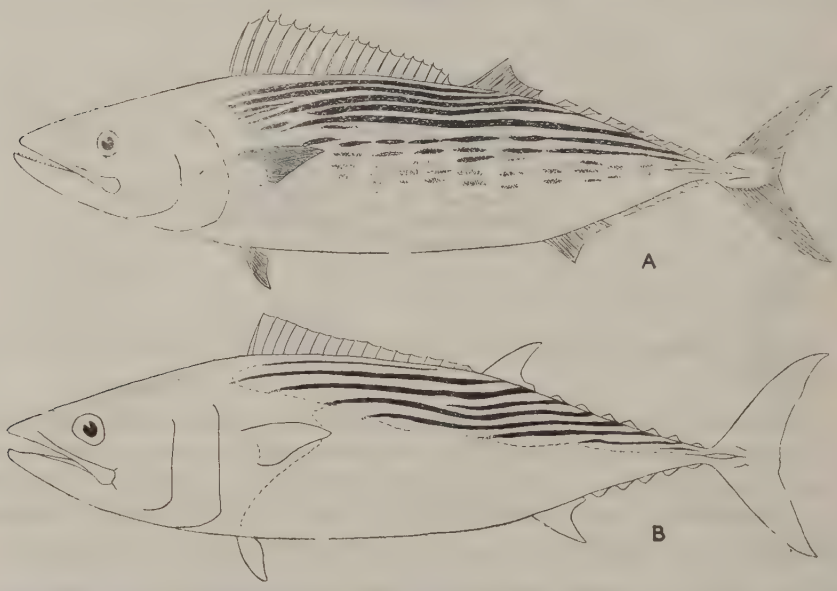

FIG. 6. *Sarda orientalis* (Temminck and Schlegal). Fig. A. 245 mm. long specimen from Vizhingam showing juvenile colouration; Fig. B. Adult (after Fraser-Brunner, 1950).

OCCURRENCE IN INDIAN WATERS.—Along the west coast. We have examined specimens from Vizhingam and Cape Comorin, the largest measuring about 51 cm.

GENERAL DISTRIBUTION.—Indo-Pacific. Its occurrence in the warmer parts of the Atlantic Ocean needs confirmation (*see* Rivas, 1951).

Genus: *GYMNOSARDA* Gill

Gymnosarda unicolor (Ruppell)

(Fig. 7)

Thynnus (*Pelamys*) *unicolor* Ruppell, 1835. *Neue Wirbelt, Fische Rothen.*

Meeres: 40, Plate 12, Fig. 1.

SYNONYMY.—Reference may be made to Fraser-Brunner (1951), Herre (1953) and Schultz (1960).

POPULAR NAME.—Dogtooth tuna.

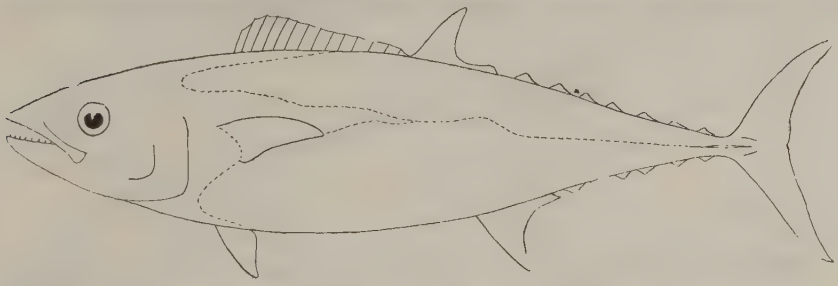

FIG. 7. *Gymnosarda unicolor* (Rüppell) (after Fraser-Brunner, 1950).

REMARKS.—Ogilby and Marshall (1954) remark that the species is said to attain 8 feet in length, but generally specimens less than 4 feet and weighing between 50 and 90 lb. are taken in the waters off Queensland. The corselet scales above the pectoral are covered by the skin so that the body appears totally scaleless. On account of this, the species is also known as the 'scaleless tuna'. The lower jaw is slightly deeper and prominent and the teeth on both jaws are well developed and conspicuous. Fraser-Brunner (1951) gives the interpelvic process of *Gymnosarda* as being bifid as in *Sarda*, and *Orcynopsis*. However, in all the specimens we have examined it is in the form of a single median blade developed to a much lesser degree than seen in *Auxis*, and would appear not to be a good diagnostic character in this case.

OCCURRENCE IN INDIAN WATERS.—Andaman Sea and Laccadive Sea. We have examined several specimens from Port Blair, Andamans and Minicoy Island, Laccadive Archipelago. The Ceylon aqualung diving expert, Mr. Rodney Jonklaas has photographed this fish underwater near the Basses Reefs, south-east of Ceylon.

GENERAL DISTRIBUTION.—Indo-Pacific, from Red Sea to Japan.

Genus: *THUNNUS* South

Thunnus thynnus orientalis (Temminck and Schlegel)

(Fig. 8)

Thynnus orientalis Temminck and Schlegel, 1850. *Fauna Japonic. Pisces*: 94.

SYNONYMY.—Reference may be made to *Thunnus thynnus* (Linnaeus) as given by Herre (1953).

POPULAR NAME.—Oriental bluefin tuna.

REMARKS.—The colouration of *Thunnus orientalis* as figured by Kishinouye (1923) shows vertical rows of spots and short bars of lighter colour

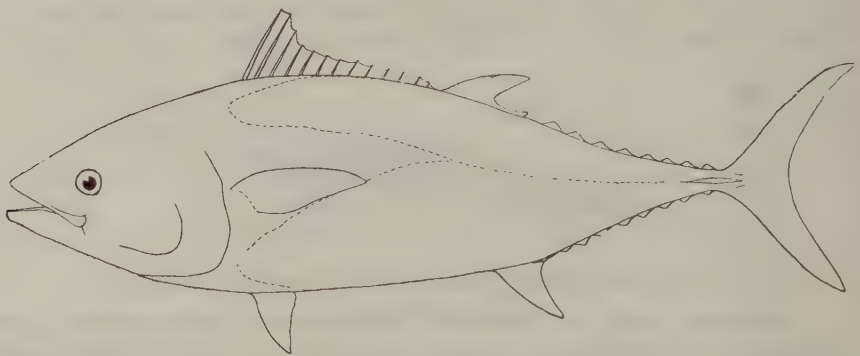

FIG. 8. *Thunnus thynnus orientalis* (Temminck and Schlegel) (after Godsil and Byers, 1944—given as *Thunnus orientalis*).

on the lower half of the body. Japanese tuna catches indicate the occurrence of *T. orientalis* in parts of the Indian seas. The differences between this and the Atlantic *Thunnus thynnus* are very slight indeed, in view of which the above nomenclature is used. It will be desirable to follow this system until such time that a detailed comparison between the Atlantic and Indo-Pacific representatives of this species is made. It is also likely that the southern bluefin tuna *Thunnus maccoyi* Castelnau may be identical with *T. t. orientalis*.

GENERAL DISTRIBUTION.—Warmer waters of the Indo-Pacific.

Thunnus alalunga (Bonnaterre)

(Fig. 9)

Thynnus alalunga Bonnaterre, 1788. *Table Ichth*: 139.

SYNONYMY.—Reference may be made to Fraser-Brunner (1950), and Rivas (1951).

POPULAR NAME.—Albacore.

REMARKS.—This species has figured in the Japanese tuna catches from parts of the Indian Seas, but has been recorded as *Thunnus germo* (Lacépède) by Japanese workers. Smith (1948) lists this as *Germo alalunga* (Bonnaterre).

Boeseman (1947) has shown that *Thynnus sibi* Temminck and Schlegel is a synonym of *Germo alalunga* (Gmelin) [= *Thunnus alalunga* (Gmelin)].

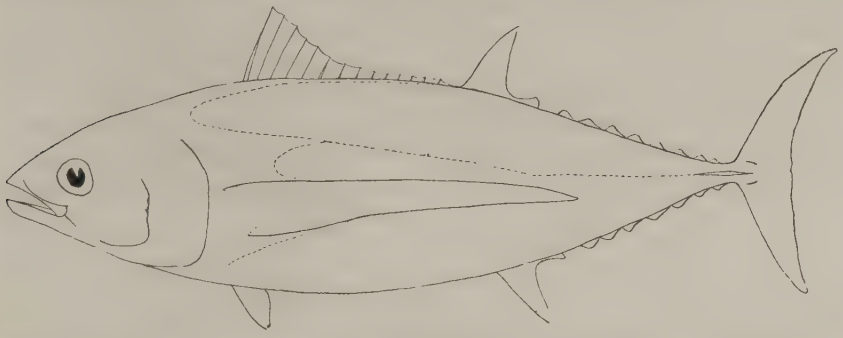

FIG. 9. *Thunnus alalunga* (Bonnaterre) (after Fraser-Brunner, 1950—given as *Thunnus* (*T*) *alalunga*).

Thunnus sibi de Beaufort (*nec* Temminck and Schlegel) is a composite grouping of more than one species. We have not examined any material of *Thunnus alalunga*.

GENERAL DISTRIBUTION.—Warmer seas of the Atlantic and Indo-Pacific.

Genus: *PARATHUNNUS* Kishinouye

Parathunnus obseus mebachi (Kishinouye)

(Fig. 10)

Thunnus mebachi Kishinouye, 1915. *Suisan Gakkwai Ho* (*Proc. Sci. Fisher. Assoc. Imperial Univ. Tokyo*), 1: 19, Plate 1, Fig. 11.

POPULAR NAME.—Big-eyed tuna.

REMARKS.—As pointed out by Munro (1957), *Thunnus mebachi* Kishinouye is very closely related to *Thunnus obseus* Lowe from the Atlantic. We find hardly any notable differences between the existing descriptions of these two species on account of which for the time being we have relegated *T. mebachi* [= *Parathunnus mebachi* (Kishinouye)] as a subspecies of the earlier proposed *T. obseus* Lowe.

Japanese records indicate its common occurrence in Indian waters. We have examined a specimen 173 mm. long from the Laccadive Archipelago obtained on one of the M.F.V. *BANGADA* cruises in 1960 which appears to be this species.

GENERAL DISTRIBUTION.—Warm waters of the Indo-Pacific.

FIG. 10. Fig. A. *Parathunnus obseus* Lowe [after Fraser-Brunner, 1950—given as *Thunnus* (*Parathunnus*) *obseus*]; Fig. B. *Parathunnus obseus mebachi* (Kishinouye) (after Godsil and Byers, 1944—given as *Parathunnus mebachi*). The pelvic fin in the fish is not spread out, but the approximate position is indicated by the arrow).

Genus: *KISHINOELLA* Jordan and Hubbs

Kishinoella tonggol (Bleeker)

(Fig. 11)

Thynnus tonggol Bleeker, 1852. *Verh. Bat. Gen.*, **24,** 89.

SYNONYMY.—Reference may be made to Serventy (1942).

POPULAR NAME.—Northern bluefin tuna.

REMARKS.—On account of the relatively long dark pectorals which generally reach to below the anterior insertion of the second dorsal, the species is often confused with the yellowfin tuna, *Neothunnus macropterus* (Temminck and Schlegel). However, in addition to the characters mentioned

in the 'Key' on p. 376, the following body colouration is very diagnostic of *K. tonggol*. The sides of the body below the level of the pectoral to the caudal keel has a series of narrow linear short lighter (whitish) streaks which are noticeable even in preserved specimens. Instead in *N. macropterus* there are a number of oblique rows of spots which often unite to form short or continuous oblique bars on the sides of the body. In some of the specimens examined, the almost vertical rows of spots alternate with whitish streaks the latter brought about as a result of the coalescence of the spots, which pattern is easily distinguishable from that seen in *K. tonggol*.

FIG. 11. *Kishinoella tonggol* (Bleeker) [after Fraser-Brunner, 1950—given as *Thunnus* (*Kishinoella*) *tonggol*].

OCCURRENCE IN INDIAN WATERS.—On the west coast from south of Bombay (Ratnagiri) to Cape Comorin; Gulf of Mannar; and the Andaman Sea. We have examined material from Mangalore, Calicut, Cochin, Vizhingam, Colachel, Tuticorin and Port Blair.

GENERAL DISTRIBUTION.—Indian Seas, East Indies, Philippine Seas, Japan and Australia. In the Eastern Pacific *K. tonggol* appears to be replaced by *K. zacalles* Jordan and Evermann.

Genus: *NEOTHUNNUS* Kishinouye

Neothunnus macropterus (Temminck and Schlegel)

(Fig. 12)

Thynnus macropterus Temminck and Schlegel, 1850. *Faun. Japonic. Pisces*, 98, Plate 51.

SYNONYMY.—Reference may be made to Herre (1953) with an exception. We have recognised *Neothunnus itosibi* Jordan and Evermann as being distinct from the typical *N. macropterus*.

POPULAR NAME.—Yellowfin tuna.

REMARKS.—The type of oblique rows of spots seen in the Yellowfin Tuna of the Indo-Pacific has not been reported in the Atlantic yellowfin tuna. It is likely that there may be additional morphometric differences between the Atlantic and Indo-Pacific forms. Considerable confusion centres around the nomenclature of the yellowfin tuna of both the Atlantic and the Indo-Pacific, so much so, an answer to the question " What is the yellowfin tuna of the Indian Seas? " is unanswerable at this stage. Deraniyagala (1952) uses the name *Thunnus* (*Neothunnus*) *argentivittatus* (Cuvier and Valenciennes) for the Indo-Pacific yellowfin tuna and mentions "Indian Ocean (Malabar)" as the type locality of *Thynnus argentivittatus* Cuvier and Valenciennes, while Rivas (1951) mentions the original description of *T. argentivittatus* to be based on material from the "Atlantic and Pacific

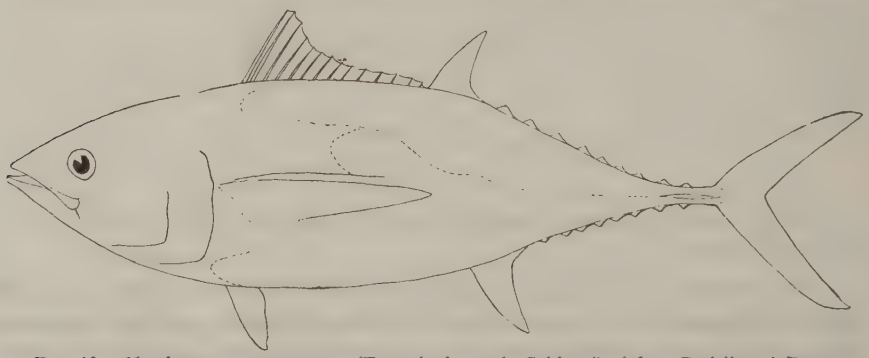

FIG. 12. *Neothunnus macropterus* (Temminck and Schlegel) (after Godsil and Byers, 1944).

Oceans". We are unable to find any reference to 'Malabar' in the original description of this species. There is no doubt that the Indo-Pacific yellowfin tuna is allied to *Thynnus albacora* Lowe (1839) originally described from Madeira in the Atlantic. Perhaps on this account, Schultz (1960) designates the northern tropical Pacific (Marshall Islands) yellowfin as *Neothunnus albacora macropterus* (Temminck and Schlegel). Until such time that a more detailed comparison of the Indo-Pacific and Atlantic yellowfin tunas can be carried out, it will be desirable to indicate the yellowfin from the Indian Seas as *Neothunnus macropterus* (Temminck and Schlegel).

OCCURRENCE IN INDIAN WATERS.—Japanese reports indicate excellent fishing grounds for this species in several parts of the Indian Ocean at certain seasons extending close to the Indian coast. We have examined specimens from the Laccadive Sea, the Gulf of Mannar and Ratnagiri.

GENERAL DISTRIBUTION.—Indo-Pacific.

Neothunnus itosibi Jordan and Evermann

(Fig. 13)

Neothunnus itosibi Jordan and Evermann, 1926. *Occ. Papers Acad. Sci.*, **12:** 22, Plate 6.

REMARKS.—This is a problematic species which in a combination of characters involving the relative length of the pectoral and the lengths of the second dorsal and anal fins shows differences from specimens of *N. macropterus* we have examined. The drawing of *Thunnus macropterus* given by Delsman and Hardenberg (1934), and also figured by de Beaufort (1951) is very much like that of *N. itosibi*. There appears to be a close resemblance between *N. itosibi* and *Thunnus allisoni* Mowbray of the Atlantic, but the latter is regarded as a growth stage of the Atlantic yellowfin tuna *N. albacora* (Lowe). After having examined specimens of *N. macropterus*

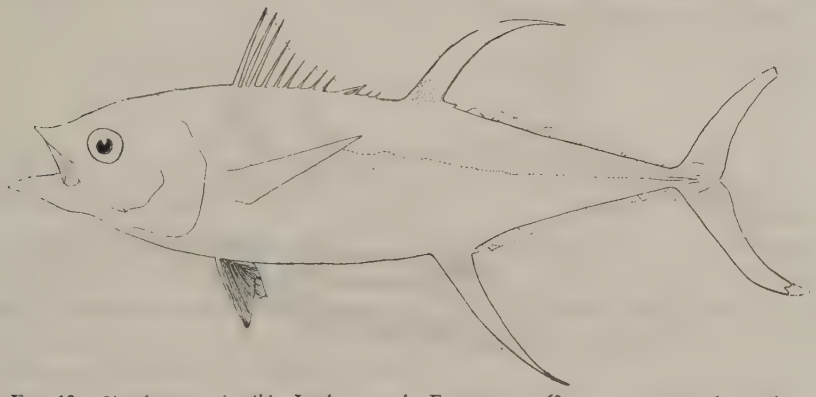

FIG. 13. *Neothunnus itosibi* Jordan and Evermann (from a mounted specimen 125 cm. long in the Madras Government Museum, Madras).

ranging from about 29 to 90 cm. and comparing them with descriptions of *N. itosibi* as well as the Madras specimen mentioned below, it is difficult to reconcile with the view that such long finned forms represent a stage of growth of the yellowfin. No doubt, eventual analysis may show that only one species of yellowfin tuna exists in all the oceans, but with our inadequate knowledge on the subject, it is premature to consider *N. macropterus* and *N. itosibi* as identical. The fact that these two types may be taken together is not conclusive that they are identical, for we have noticed two closely related species of *Auxis* (*A. thazard* and *A. thynnoides*) occurring in the same

school to mention but one instance. So until more information is forthcoming it will be desirable to retain *N. itosibi* as distinct from *N. macropterus*. From Indian waters, we refer to this species one specimen 125 cm. long (Fig. 13) from Madras, mounted in the Madras Government Museum and labelled as *Thynnus macropterus*.

GENERAL DISTRIBUTION.—Indo-Pacific.

Genus: *KATSUWONUS* Kishinouye

Katsuwonus pelamis (Linnaeus)

(Fig. 14)

Scomber pelamis Linnaeus, 1758. *Syst. Nat.*, ed., **10**: 297.

SYNONYM.—Reference may be made to de Beaufort (1951) under *Euthynnus pelamis* (Linnaeus).

POPULAR NAME.—Oceanic skipjack.

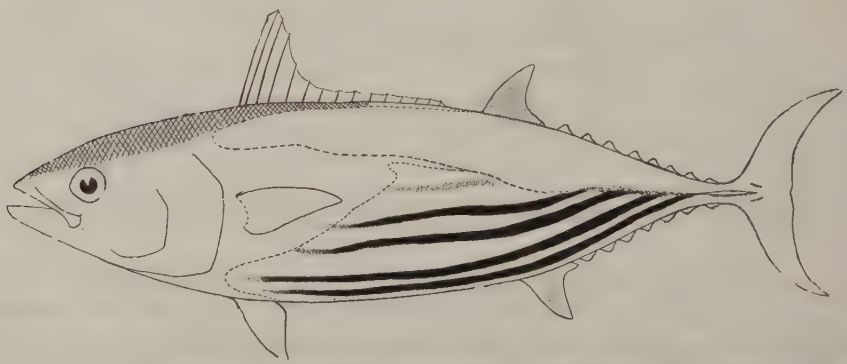

FIG. 14. *Katsuwonus pelamis* (Linnaeus) [after Fraser-Brunner, 1950—given as *Euthynnus* (*Katsuwonus*) *pelamis*].

OCCURRENCE IN INDIAN WATERS.—Very well known species forming an important fishery at the Minicoy Island in the Laccadive Archipelago (Jones, 1959, and Jones and Kumaran, 1959) and schools may stray into coastal waters as evidenced from occasional catches at Vizhingam, Ratnagiri and other centres on the west coast and at Tuticorin in the Gulf of Mannar. We have examined several specimens from the Laccadive Sea.

GENERAL DISTRIBUTION.—Indo-Pacific and Atlantic.

Genus: *EUTHYNNUS* Lütken

Euthynnus affinis affinis (Cantor)

(Fig. 15)

Thynnus affinis Cantor, 1850. *Journ. Asiat. Soc. Bengal*, **18:** 1088.

SYNONYMY.—Reference may be made to de Beaufort (1951) [who designates this as *E. alletteratus affinis* (Cantor)] with one exception. We consider *Euthynnus yaito* Kishinouye as a possible subspecies of *E. affinis* (Cantor).

POPULAR NAME.—Little tunny.

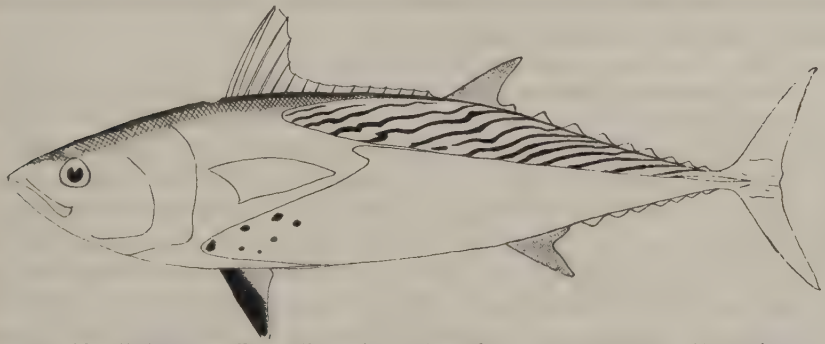

FIG. 15. *Euthynnus affinis affinis* (Cantor) [after Fraser-Brunner, 1950—given as *Euthynnus* (*Euthynnus*) *affinis affinis*].

REMARKS.—As Fraser-Brunner (1950) has indicated, the differences between *E. affinis* and *E. alletteratus* Rafinesque, the latter from the Atlantic, are of sufficient magnitude to consider them as being specifically distinct. The Eastern Pacific form *E. lineatus* Kishinouye as indicated by Godsil (1954) appears to be a distinct species.

OCCURRENCE IN INDIAN WATERS.—*E. a. affinis* occurs at several places along the west and east coasts of India and forms a fishery of some magnitude at several centres. We have examined specimens from Vizhingam, Laccadive Sea, Gulf of Mannar, and Andaman Sea. Through the kindness of Mr. Soong Ming Kong, Director of Fisheries, Malaya, we have been able to examine typical specimens of *E. a. affinis* from Malayan waters. Mr. John C. Marr, Chief, Pacific Oceanic Fisheries Investigations, Hawaii, has sent us a specimen of *E. affinis yaito* for comparison.

GENERAL DISTRIBUTION.—Indian Ocean and probably also parts of Western Pacific.

General Remarks

This study has been mainly aimed at recording the tuna and tuna-like fishes which occur in the Indian Seas, and also in facilitating their identification as the available information about them is comparatively meagre. Being primarily oceanic fishes, with the existing gears such as shore-seine, gill net, and hook and line, only small percentages of shoals which stray into the shallow coastal waters are liable to be captured except *Euthynnus*, *Kishinoella* and *Auxis*. Secondly for fresh consumption they are not as much favoured for instance as the seer fish [*Scombermorus* (*Cybium*) *commerson*]. The absence of a comprehensive work on the species occurring in Indian seas has been another handicap, which deficiency it is hoped this review will help in partly rectifying.

The question of nomenclature has been a difficult one to arrive at any unanimity in the case of certain species of the tunas especially as no detailed comparision of the almost similar forms occurring in the Indo-Pacific and the Atlantic Oceans has been so far carried out. We are unable to say whether even within the distributional limits of the species in the Indo-Pacific, geographical races or subspecies can be differentiated with the possible exception of *Euthynnus affinis*. Although Fraser-Brunner's revision of the Scombridae (1950) settles some of the broader questions, such as the desirability of grouping all scombroid fishes under one family, etc., ichthyologists may not fully agree with the treatment given at the species level. The large size and the consequent difficulties of preservation and hence the non-availability of good series of specimens in Museum collections have been very great handicaps to systematists who have worked on these fishes so much so, reliance had to be placed on earlier, often inadequate and ambiguous descriptions or poorly preserved specimens. Although creditable work has been done in advancing our knowledge, yet due to the aforesaid reasons errors have crept in even in standard works which are widely consulted. For instance, we find that *Thunnus sibi* de Beaufort (*nec* Temminck and Schlegel) refers in part also to *Parathunnus obseus mebachi* (Kishinouye), and to *Kishinoella zacalles* Jordan and Evermann. The fishery biologist who will have an opportunity to examine fresh specimens of small as well as large tunas in the field should be able to help considerably in elucidating several of the unanswered questions.

The yellowfin tunas which may be conveniently grouped as *Neothunnus albacora*-complex is yet another composite group which calls for intensive study. Some of the differences, such as the relative length of the fins which

were treated as characters of importance in specific discrimination have been attributed by some workers to be different growth stages of one and the same species. But in all cases, comparison with good series of specimens are lacking and deductions based on stray specimens may not be conclusive. This leads us to the questions as to: what in fact is the yellowfin tuna of the Indian Seas? Are *Neothunnus macropterus* and *N. itosibi* only nominal species? or whether these two species are only growth stages of one circumtropical species *N. albacora*? or whether they are geographical races of *N. albacora*? or whether they represent two almost identical species of the category which taxonomists call as sibiling species? The fact that long-finned and short-finned forms may be taken from the same school need not necessarily follow that they belong to one and the same species, as the occurrence of mixed schools of tunas are not uncommon. We have noticed both species of *Auxis*, *A. thazard* and *A. thynnoides* occurring in the same school and Matsumoto (1960) mentions of similar occurrence.

Multitudinal are the problems that require solving as regards tuna systematics are concerned. We have felt it unnecessary to add to the burden by citing local names used for some of these fishes along various parts of the Indian coast in this review for the following reasons. More than one species is sometimes denoted by the same name or the same species is given different names at different places even in the same linguistic area. Another fact is that only within the last few years with the advent of mechanised boats it has been possible to take some of these fishes from the offshore waters and local names do not exist for some of the species. Considering the need for the standardisation of the popular names of these fishes, we have chosen the most widely current terms in usage in English and where such a name is not already available no attempt has been made to coin any new name.

Another aspect worth mentioning is our complete lack of data regarding the maximum sizes attained by the various species of tunas in Indian Seas. While the frigate mackerels and the oceanic skipjack and the little tunny do not attain large sizes, at the other extreme are the yellowfin tuna, the big-eyed tuna, etc., which grow to considerable size but for which there is practically no data (as to the species, size, weight, sex, etc.) from this area.

Tunas constitute the most potentially important group of oceanic fishes in our waters and the success of our oceanic fisheries programme depends almost entirely to the development of this latent resource. It is hoped that this review will help in as well as stimulate interest towards the proper documentation of data regarding these fishes.

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VELOCITY OF SOUND IN THE ARABIAN SEA ALONG THE SOUTH MALABAR COAST DURING THE POST-MONSOON SEASON

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1. Introduction

The knowledge of the sound distribution in the sea is of importance in fathmetry and in sonar studies. It is with a view to find the corrections to various echo-sounders with different 'sounding velocities' for use in the Arabian Sea, along the South-Western coast of India, this study has been undertaken. As a preliminary, the results for the period immediately after the South-West monsoon only, are given in this paper. As it would be of interest for further studies in locating the subsurface barriers by sonic method and because of the importance of the sound velocity in under-water acoustics, the distribution of sound velocity is fully discussed without making any special reference to the individual problems.

2. Data and Methods

The velocity of sound in any medium is obtained from the formula:

$$V = \sqrt{\frac{\text{Elasticity}}{\text{Density}}}$$

and for sea-water this equation takes the form

$$V = \sqrt{\frac{\gamma}{\rho\beta}}$$

where γ is the ratio of specific heats Cp/Cv, ρ the density of the medium and β the isothermal compressibility. As these quantities can be derived from temperature, salinity and pressure and making use of some of the physical properties of sea water, the velocity of sound can be computed from the basic oceanographic parameters. As the final expressions for different quantities involved are very complicated, different tables are in use for the computations.

Kuwahara's Tables (1939) are used for the present computations. These tables were based on various empirical formulæ derived by Knudsen (1901),

Ekman (1908), etc. Further he had to take some of the physical constants whose values are questionable to some extent in the light of the modern techniques developed for the same. Thus, considering Del Grosso's (1952) recent formula, Beyer (1954) has concluded that Kuwahara's value are almost consistently smaller by about 3 m./sec. amounting to maximum error of 0·2%. The maximum correction to be applied to the echo-sounders up to 500 m. (to which depth this investigation is extended) does not exceed 20 m. For the same layer, with the sound velocities encountered, the error involved by using Kuwahara's Table for the computation of sound velocities, instead of Del Grosso's formula, would be nearly + 1 meter. But considering the standard deviation of about 3 m. sec. reckoned from the mean profile of the sound velocity against depth for the data used herein, from which the corrections are evaluated, the said uncertainty of Kuwahara's values is within the observational limits. Thus for the purpose, Kuwahara's values are quite adequate. The general discussion of the sound velocity distribution, also, will not be affected by the tables employed here.

The collection and the preliminary analysis of the data employed herein, are completely discussed separately by Rama Sastry and Myrland (1959). However, the station positions are indicated in the chart showing the sound velocity distributions (Fig. 10) for reference.

In the following sections, the computed sound velocities are represented diagrammatically both in vertical sections off the coast-line from Alleppey (9 30' N) to the Cape Comorin (8° N) and by horizontal charts corresponding to all the international levels from the sea surface to 150 m.; though only four charts are reproduced.

3. Vertical Sections of Sound Velocity

It is profitable to have some knowledge about the oceanographic conditions of the region during the period before discussing the sound velocity distribution. The essential features are reproduced here from Rama Sastry and Myrland (19 9). During this season upwelling along the coast is limited only to the upper 75 m. and the in.ensity increases southwards. The northern boundary of intense upwelling can be considered as 9° N. The space time variation of salinity is from 34–36‰; and a subsurface zone of maximum salinity occurs at a mean depth of 300 m. Salinity is generally lower near the bottom of the continental shelf and the slope. A vertical plane at the edge of the continental shelf forms a boundary between the low saline coastal waters and the high saline oceanic waters. Vertically isothermal water mass, 'The Kerala Coastal Deepwater' forms over the bottom

of the continental shelf and this water, during the season, is not continuous, but appears either very near the coast or near the edge of the shelf. With higher densities coastwards from surface up to 50 m., the main current is southerly. But at depths greater than 100 m. a northerly counter current entering in the southernmost region branches off westwards, north of 9° 30′ N. Between 50 m. and 75 m. circulation is transitory and an easterly

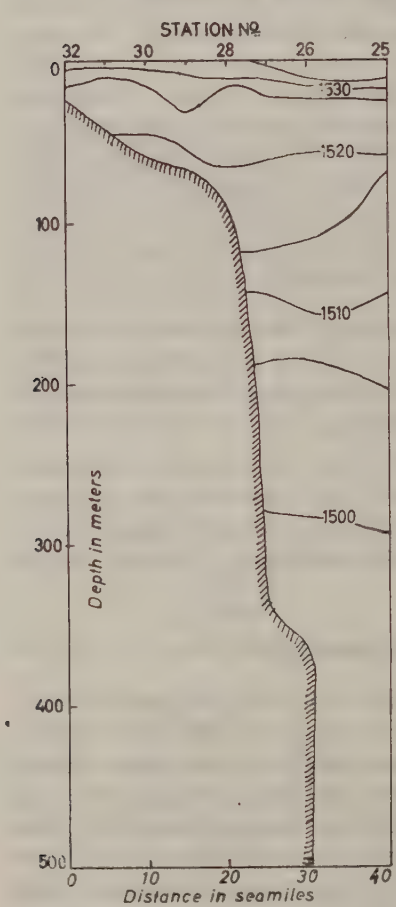

FIG. 1

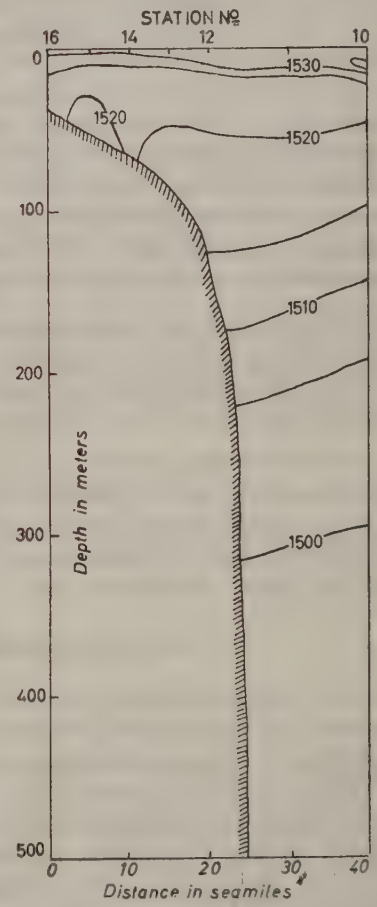

FIG. 2

FIG. 1. Distribution of sound velocity in a vertical section off Alleppey (Mean latitude 9°30′ N) on the 19th September 1957—vertical exaggeration is 371 and is constant for all vertical sections.

FIG. 2. Distribution of sound velocity in a vertical section at 10 miles south of Alleppey (mean latitude 9° 20′ N) on 18th September 1957.

flow is indicated in the southern region particularly at 50 m. Eddy circulations centered at 9° N and 76° E appear down to a maximum depth of 50 m.

Now bearing in mind all these facts, first we proceed to discuss the vertical section from the northernmost section, *i.e.*, off Alleppey. All the sections up to the Cape Comorin are running due west on different parallels except the southernmost one which is south-westerly.

As the distribution of temperature has profound influence, the isopleths of sound velocity follow closely the corresponding isotherms. Thus in Figs. 1 and 2 off Alleppey corresponding to the mean latitudes 9° 30′ N and 9°20′ N the isopleths of 1535–1520 m./sec. show an upward tilt coastwards associated with upwelling. The wave-like structure of the isopleths near the bottom of the continental shelf, in both these figures as well as the others to follow are the result of the Kerala coastal deepwater. But in the surface layers it is the result of surges of upwelling where either discontinuity in salinity or wave formation of isotherms could be noticed. The vertical gradient of sound velocity is uniform between 100 and 300 m. as a result of steady fall of temperature. Both because of the existence of a zone of subsurface maximum of salinity and of the influence of pressure (the isothermal compressibility) the rate of fall of sound velocity with depth in deepwaters below a depth of 300 m. is minimised.

In a section 10 miles north off Quilon (Fig. 3) with the increased thickness of the Kerala coastal deepwater between stations 14 and 15 a discontinuity in the isopleth of 1520 m./sec. is found. With reduced vertical gradients of temperature between 25 and 100 m., the gradient in sound velocity has also decreased. The downward tilt of the isopleths in this as well as in the following section off Quilon (Fig. 4) is the result of a corresponding reduction in density followed by the presence of low saline waters along the bottom. But off Quilon it is likely that the distribution is also affected by the bottom topography and internal waves. In the surface layers even from the sound velocity section, it is clear that intense upwelling starts here, with the result sound velocity near the coast in the surface layers has decreased by about 10 m./sec. compared to the previous section. Also with the subsurface counter-flow starting at about 50 m. which is being reflected near bottom producing turbulence (lateral mixing) resulted in eliminating the Kerala coastal water. But purely associated with the turbulence the isopleths of sound velocity are of wave form.

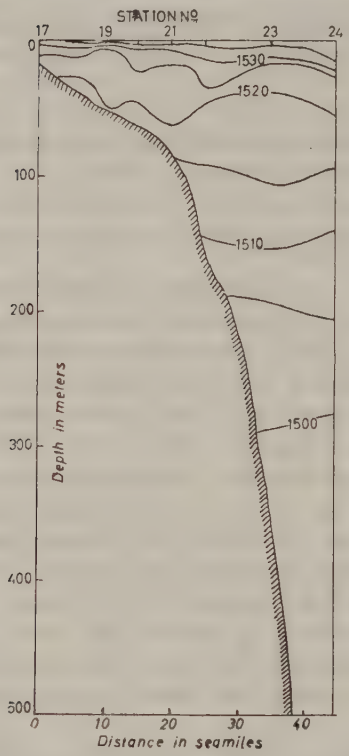

FIG. 3. Distribution of sound velocity in a vertical section running due east 10 miles north off Quilon (mean latitude 9° 10' N) on the 18th September 1957.

Further south there is a general increase of sound velocity in the surface layers though there is no corresponding change in deep layers. This change is maximum in the clear oceanic waters (roughly beyond the continental slope) where the thermocline forms at about 30 m. The closed isopleths of 1540 m./sec. (Figs. 5 and 7) are in fact associated with temperature inversions found in the mixed layer. These may be considered as purely incidental as they occur in very shallow depths affected by the diurnal variation of temperature, whose influence could not be eliminated in this investigation for want of data.

In Figs. 5 and 6 (between Quilon and Trivandrum) the vertical gradient of sound velocity near bottom is very small because of the "Kerala coastal deepwater," wherein in addition to the vertical gradient, the lateral gradient of temperature also is very small (less than 1° C. fall in about 10 miles seawards).

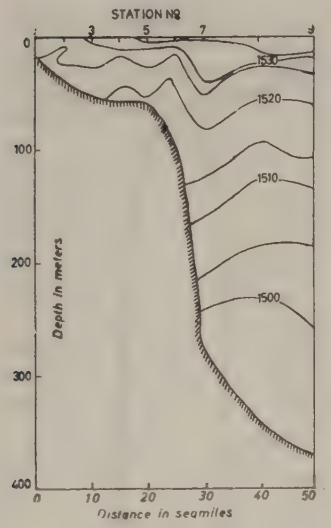

FIG. 4

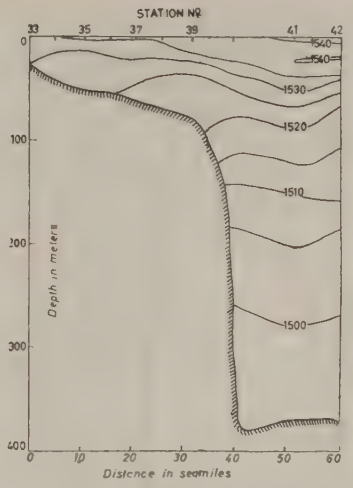

FIG. 5

FIG. 4. Distribution of sound velocity in a vertical section at Quilon (mean latitude 9° N) on 16th and 17th September 1957.

FIG. 5. Distribution of sound velocity in a vertical section at 7 miles south off Quilon (mean latitude 8° 45′ N) on the 5th October 1957.

Between Trivandrum and the Cape Comorin (Figs. 7 and 8) corresponding to latitudes 8° 15′ N and 8° N the velocity distribution of sound is similar to the previous sections in the upper 100 m. but below the depth the isopleths are more orderly. But in an oblique section of Cape Comorin (Fig. 9) associated with lateral mixing in the direction of the current the isopleths in the upper 100 m. show the characteristic wave form.

4. Distribution of Sound Velocity at Different Levels

Horizontal charts showing the sound velocity distribution at 0 m., 20 m., 50 m. and 100 m. are given in Fig. 10. However, the following discussion would include for other levels up to standard 150 m. so that the intermediate changes could be easily visualised.

At the sea-surface (Fig. 10 A) the sound velocity increases uniformly away from the coast and the isopleths from 1534–1540 m. sec. between 7° N and 9° N are nearly parallel to the coast. But off Quilon, the isopleths 1536–1540 m. sec. are eastwards, and north of 9° N associated eddy formations there is a break in the continuity of the isopleths. This break at 9° N forms a channel of rapidly increasing values southwards across it. This sound channel, at 10 m., with a velocity range from 1526–1534 m./sec.

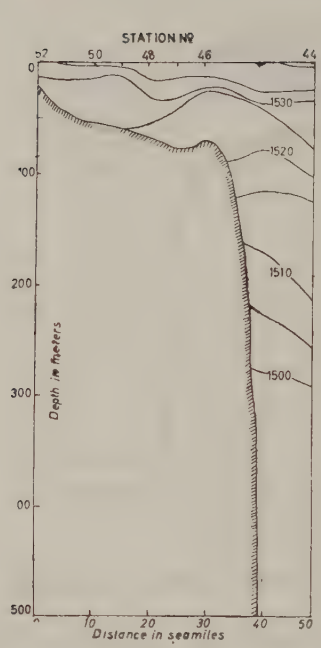

FIG. 6

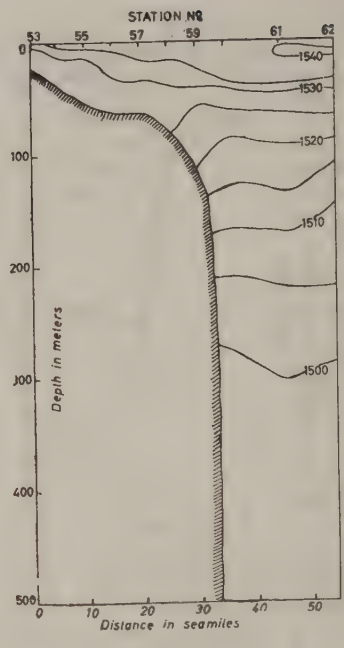

FIG. 7

FIG. 6. Distribution of sound velocity in a vertical section entering coastwards at about 7 miles north of Trivandrum (mean latitude 8° 30′ N) on 5th and 6th October 1957.

FIG. 7. Distribution of sound velocity in a vertical section at 8 miles south of Trivandrum (mean latitude 8° 15′ N) on 6th and 7th October 1957.

proceeds from Quilon in westerly direction converging at 9° N and 76° E where the mean width is only 7 miles (North to North-East) diverging as it proceeds north with a maximum separation of the same isopleths being about 20 miles off Alleppey. The isopleths of higher values up to 1540 m./sec. more or less retain their shape between 7° N and 9° N but turn north-easterly round the sound channel.

At least up to 20 miles off Quilon the sound channel is not very prominent at 20 m. (Fig. 10 B) but the maximum horizontal gradients occur approximately at the same position as at 10 m. and a change of 1524–1538 m./sec. occurs in 13 miles along 76° E. From this position two diverging channels one going northwards and the other running in an easterly direction. Though there is a fall of 2 m./sec. in 20 m. the isopleths south of 9° N are similar to those at the surface.

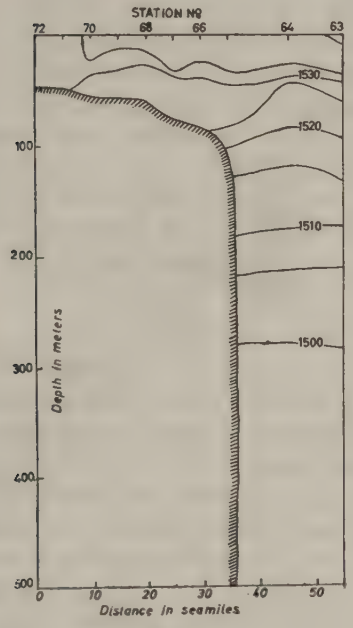

FIG. 8

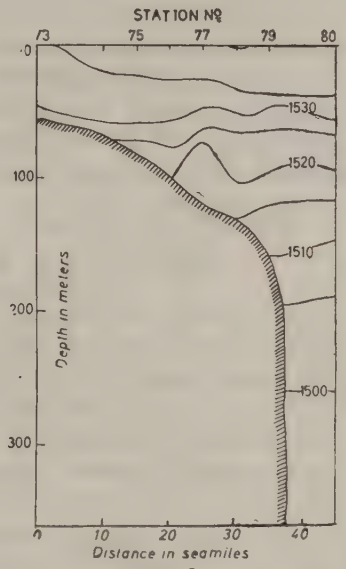

FIG. 9

FIG. 8. Distribution of sound velocity in a vertical section proceeding eastwards to the Cape Comorin (mean latitude 8° N) on the 7th October 1957.

FIG. 9. Distribution of sound velocity in a south-westerly vertical section of the Cape Comorin on 7th and 8th October 1957.

The isopleths running nearly parallel to the coast in the southern zone at 30 m. converge at 8° 30′ N and 76° 30′ E and then form two individual channels one converging nearly at the same point as at higher levels with the other isopleths northwards and the other continuing its north-westerly path. Both these systems merge together at 8° 50′ N and 75° 30′ E resulting a strong southerly horizontal gradient from 1528–1540 within 10 miles.

This characteristics still prevails at 50 m. (Fig. 10 C) where within a channel width of 10 miles the sound velocity increases from 1521–1526 and here this channel seems to turn towards south-west which in fact becomes south-westerly at 75 m. With the redistribution of mass at these transitory levels the isopleths in the south tend to be westerly to south-westerly. But between 7° 30′ and 8° 30′ at 75 m. the isolines run parallel to the coast beyond the continental slope. Thus the westerly increase of sound velocity in the upper layers has gradually turned to be a southerly increase.

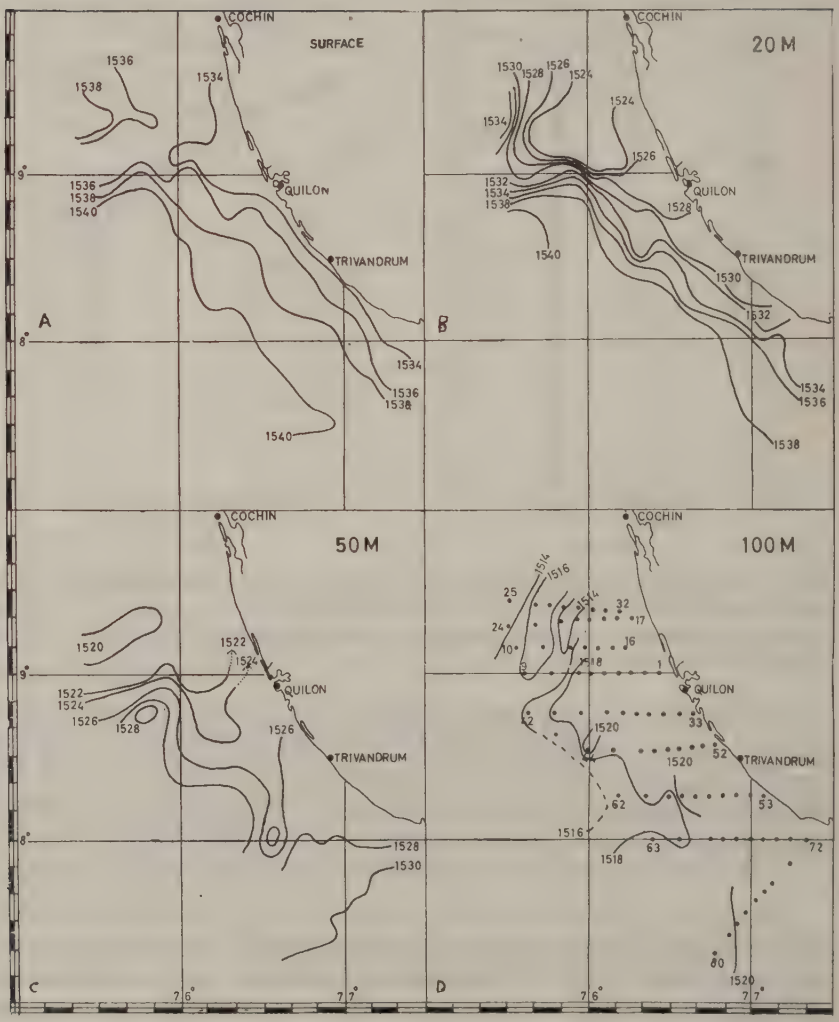

FIG. 10. Chart showing the distribution of sound velocity at 0 m, 20 m, 50 & 100 m depth levels—The station positions are indicated in the figure.

With lower temperatures and higher densities seawards, at 100 m. (Fig. 10 D) the sound velocity is decreasing away from the coast. With still unsettled conditions in the north and with initial stages of the branching of the subsurface flow towards north-west the isopleth of sound velocity are not continuous. It is in this region the velocity of sound still shows a rapid increase southwards. At 150 m. the range of the sound velocity encountered is only 4 m./sec. with a maximum horizontal range of 3 m./sec. (from 1513 m./sec. near the coast to 1510 m./sec. westwards). In the region north of Trivandrum the sound velocity is uniform with mean value of 1510 m./sec.

5. Correction Tables for Echo Sounders

Corrections to be applied for echo-sounders of different sounding velocities ranging from 1450–1540 m./sec. are computed from a total of 512 computed velocities at individual levels in the region covered by 80 stations. At the first 32 stations covering the region north 9° N observations were made from 16th–19th September 1957, while the remaining stations covering the southern region were established between 5th–9th October. In order to see whether there is any effective change in the computed values by the time difference in making the observations each of the series were separately treated to arrive at the mean profiles of sound velocity against depth from which for any sounding velocity the required correction can be computed. It is found that even by combining these values, one could get the corrections within the reasonable limits of accuracy.

As the correction table is to be applicable to the entire region, for the post-monsoon season, the variability of the observations distributed both in space and time has been worked out and only the mean values of sound velocity at different depths for the individual months and for the whole season together with the standard deviations calculated from these means are given in Table I.

Most of the changes affecting the sound velocity occur in the upper 100 m. Thus when the upper 100 m. are not considered the stand deviation becomes half of the original value. Because of this degree of variance as has been said earlier, Kuwahara's computations would be within the desired accuracy.

In Table II the corrections to be added to the depth given by the echo-sounders of different sounding velocities are given. These values have been computed from the mean vertical distribution of sound velocity.

TABLE I

Time and space means of sound velocity together with the standard deviations derived from them for the data

Depth (metres)	Mean sound velocity m./sec.$^{-1}$ September	October	Post-monsoon	Standard deviations for
0	1534·71	1537·75	1536·52	
10	1529·80	1536·21	1533·69	
20	1525·91	1534·23	1531·05	September = 2·72
30	1522·95	1531·99	1528·34	
50	1520·33	1527·02	1524·36	
75	1518·27	1523·00	1520·95	
100	1515·89	1518·70	1517·40	October = 2·88
150	1510·05	1511·75	1510·93	
200	1505·91	1505·61	1505·24	
300	1499·14	1499·01	1499·06	
400	1497·59	1497·60	1497·59	The season=2·81
500	1498·45	1496·92	1497·53	

6. CONCLUSION

1. Though Del Grosso's formulæ are expected to give more reliable values for sound velocity, for the computation of correction tables for use in limited regions during a particular period of the year, Kuwahara's sound velocity tables are sufficiently accurate.

2. Maximum vertical gradient of sound velocity occurs in the top 50 m., during the period of upwelling, and the gradient remains steady in the layer between 100–300 m. At still greater depths the decrease in sound velocity due to temperature change is compensated by the pressure and thus the rate of fall is very small.

TABLE II

Correction in metres to be added to the echo-sounder-readings for different sounding velocities of echo-sounders

Depth obtained from echo-sounder (m.)	Sound velocity m./sec.$^{-1}$									
	1450	1460	1470	1480	1490	1500	1510	1520	1530	1540
0	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00
10	0·55	0·49	0·42	0·36	0·29	0·23	0·16	0·10	0·03	−0·03
20	1·09	0·96	0·83	0·70	0·57	0·44	0·31	0·18	0·05	−0·08
30	1·61	1·42	1·22	1·02	0·83	0·63	0·44	0·24	0·04	−0·15
50	2·61	2·29	1·95	1·63	1·30	0·97	0·65	0·32	−0·01	−0·33
75	3·80	3·31	2·82	2·33	1·84	1·35	0·86	0·36	−0·13	−0·62
100	4·94	4·29	3·62	2·97	2·32	1·66	1·01	0·34	−0·31	−0·96
150	7·06	6·07	5·08	4·09	3·11	2·13	1·14	0·15	−0·84	−1·82
200	8·98	7·66	6·30	5·02	3·71	2·39	1·07	−0·26	−1·58	−2·88
300	12·43	10·45	8·41	6·47	4·49	2·51	0·53	−1·47	−3·46	−5·42
400	15·69	13·01	10·30	7·68	5·05	2·39	−0·75	−2·93	−5·59	−8·21
500	18·79	15·49	12·10	8·82	5·52	2·19	−1·12	−4·67	−7·79	−11·07

3. During the post-monsoon, in the region if an echo-sounder calibrated at a sounding velocity of 1510 m./sec. be used, corrections up to 500 m. will be very small.

4. A sound channel running westwards from Quilon to about 30 miles and there turning northwards is found between 10 m. and 50 m. depth. At deeper depths this channel seems to have an eastward branch with other isopleths converging with it at 9° N and 76° E.

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A PRELIMINARY ACCOUNT OF THE EXPERIMENTAL ROCK-LOBSTER FISHING CONDUCTED ALONG THE SOUTH-WEST COAST OF INDIA WITH BOTTOM-SET GILL NETS

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Introduction

The authors in the present communication describe the details of the preliminary experiments conducted by them on the South West Coast of Peninsular India for the introduction of a new fishing gear for Rock Lobsters.

The hard rocky bottoms of the sea below the tidal zone are usually the abode of the Rock Lobsters. They hide in the crevices and inside the holes of submerged rocks and lurk on stony corals and sea weed beds. Similar ecological conditions exist in certain areas off the East and West coast of India and is suggestive of an abundance of this Decapod crustacea. Though the resources for lobsters appear to be extensive, systematic exploitations have not so far been organised. From the available records of the total annual landing of shell-fishes in India, it has not been possible to assess the actual quantity of lobsters landed each year. During the preliminary survey conducted by the authors, it has been estimated that during the 1956–57 season about 5,95,000 lobsters weighing 1,13,400 kg. (2,50,000 lb.) and valued at Rs. 1,98,000 were landed along the twenty mile stretch of the West Coast extending from Collachel to Kanyakumari. According to Miyamoto and Shariff (1958) in Muttam village alone during 1957–58 season about 53,998·4 kg. (1,19,044 lb.) of lobsters were landed. Chacko and George (1958) have recorded that in a good fishing season 6,500 lobsters can be collected per day from Muttam and nearby villages.

Lobsters fetch a reasonable price in several markets in India and they are always held in high esteem in the markets of Bombay and Calcutta. In the South-West Coast of India, where the present series of experiments were conducted, the price offered by some freezing companies ranged from Rs. 0·25 to Rs. 0·88 per lobster depending on their size. For sometime past, the Indian Rock Lobsters are greatly sought for in the foreign markets

of U.S.A. and Australia. Consequent on the increasing demand from foreign countries, several freezing and canning factories have been established along the West Coast of India and appreciable quantities of particularly frozen lobster tails are exported annually. Never before was there such a demand for Indian lobsters abroad as it is now. The possibility of earning enough of foreign exchange by increased exports might perhaps give a new fillip to this hitherto less exploited industry.

Four species of Rock Lobsters belonging to the genus *Panulirus* have been hitherto recorded from Indian waters. Gravely (1927) has indicated the occurrence of *Panulirus dasypus* in the littoral fauna of Krusadai in the Gulf of Mannar. Rai (1933) has mentioned that *P. ornatus* and *P. fasciatus* are commonly found on the Bombay coast. Chopra (1939 and 1943) has stressed the importance of lobster as a valuable food item just like prawns and crabs and has further stated that the common species available along the East Coast is *P. polyphagus* while *P. ornatus* is common in Bombay waters.

A Brief Account of the Existing Methods of Fishing

Season for lobsters in the South-West Coast commences during the month of November of one year and extends up to March of the succeeding year. The local fishermen employ different indigenous gear for catching them. Traps, anchor hooks and line and scoop nets are the common gear used. In certain places, occasionally old pieces of surface hemp drift nets are converted as bottom set nets for catching of lobsters. A comprehensive account describing in detail the traps and anchor hook and their methods of operation along this coast has been given by Miyamoto and Shariff (1958). However, a brief descriptive resume of the various gear and their methods of operation for lobsters is presented below:

(*a*) *Lobster traps.*—Lobster traps or pots are the conventional fishing gear vastly employed all over the world for the catching of lobsters and they account for the entire catch of these Decapods in countries like Canada and Australia. The lobster traps operated along the South-West Coast of India are made of vegetable fibres extracted from the leaf stalk of Date-palm tree (*Phœnix sylvestris*) locally available. They are constructed in the form of a heart-shaped contrivance measuring about 76·2 cm. in length, 60·9 cm. in breadth and 53·3 cm. in height. The entire construction is such that the trap can easily be separated into three pieces and can also be assembled together with ease. This enables the operator for the easy removal of the catch and for placing the bait and sinkers inside. Though

these traps differ from the perch traps of Gulf of Mannar described by Prabhu (1954) in their construction and material, the method of operation is similar. After baiting with live sea-mussel (*Mytilus* spp.) and placing granite stone sinkers inside the traps, they are set on fishing grounds lying within a mile away from the shore line and at depths ranging from 5·52–14·72 m. A fisherman dives down to the rocky bottom for setting the trap. On an average, about 10 traps are set by a single catamaran unit of two fishermen. The next day the same ground is located with the guidance of shore bearings and the traps are hauled up one by one by diving. The catches emptied, the traps are laid again after replenishing the bait.

(*b*) *Anchor hooks.*—An anchor hook essentially consists of a 12·7 cm. long iron rod bent in the form of a hook with 6 upwardly curved pointed arms. To this hook is attached a brass snood of ·305 m. long which in turn is attached to 46·0 to 55·2 m. of cotton twine forming the hand-line. To lure the lobsters, sufficient quantity of mussel meat is fastened to the brass snood with thin fibres of Agave. Generally, the fishing is conducted from a catamaran during nights, when the lobsters are expected to have a nocturnal ramble near their rocky abode. The hand-line with the baited hook attached to the snood is released to the bottom of the sea. As soon as the bite of the lobster is felt through the hand-line, the operator pulls up the hook with such a force that the body of the lobster that happens to come near the bait is pierced by the sharp arms of the hook. The hooked lobster is hauled up and the operation is continued after rebaiting. The bottom being rocky, at times the hook gets caught among the rocks. On such occasions, a stone messenger locally known as "*Sarani*" (Tamil) is let down through the hand-line which strikes the entangled hook and effects its immediate release.

(*c*) *Line and scoop net.*—This type of fishing is done with the help of two implements, the one being the cotton line and the other the scoop net. The line consists of 18·4 to 27·6 m. length of cotton twine (20/15/3) to one end of which a small sinker is attached by means of coir rope of 0·62 cm. diameter and of 0·91 m. length. The scoop net is made as follows:

About 2·15 m. bamboo of 1·92 cm. diameter is taken, bent in the form of a circular ring and tied with coir rope leaving a small handle. A piece of cotton webbing of 85 meshes at top, 40 meshes at bottom, 16 meshes in depth and 5·08 cm. mesh is laced to the above circular frame with nearly 55% take up and both free edges and bottom are laced to form a funnel-shaped bag. During nights, the lines with sufficient mussel meat attached to it, are released from a catamaran to the bottom of the rocky lobster

fishing ground. As soon as the bite of the lobster is felt, unlike as in the anchor hook operation, the line is very slowly hauled up with least disturbance. The lobster is thus lured by the bait and comes to the surface when it is quickly scooped with the help of the scoop net.

(*d*) *Net fishing*.—Rarely the local fishermen use nets for the catching of lobsters. But, in a fishing village at Collachel, fishermen have been found to use some old pieces of surface drift nets after converting them as bottom sets. Each piece of surface net is made of hemp twine and measures 250 meshes long, 50 meshes deep with 14·47 cm. mesh size in stretched condition. 0·84 cm. diameter coir rope forms the head-rope and there is no foot-rope. The net has usually a hang up of 45% and it is generally operated as a surface drift net. When these nets become old, several pieces, usually about 8, are joined together and attaching 2 to 3 stone sinkers weighing about 1·81 kg. each to the bottom webbings, they are set at the bottom. The net is buoyed up with nearly 8 floats made of local light wood (*Albizzia* spp.) attached to the coir head-rope. They are operated adjoining rocky beds at 9·20 to 14·72 m. deep. The fishing operations are conducted from a small catamaran during nights and the nets are hauled the next morning. Along with lobsters, few fishes are also caught.

Need for the New Gear and Recommended Requisites for the New Design

A close study of the existing indigenous lobster gear and their methods of operation have revealed the fact that each system of fishing has its own merits and demerits. All the existing types of gear are only operated very near the shore with the result the area of operation is very much limited. Lobsters caught by the anchor hook are very often badly injured. Injured lobsters are not good for freezing. The line and the scoop net fishing appear most ideal as it can catch lobsters alive. But the method of operation is, however, time-consuming and requires special experience in handling the line and the net. There are more chances for the lobsters to escape without being caught in this gear. As the fishing operations are conducted only during nights, the fishermen have to keep awake all through the night. Setting of the lobster traps at the sea-bottom involves considerable risk and hardship. The fishermen have to dive down to various depths every time a trap is set or hauled up. Each catamaran can set at best 12 traps a day. The catch always depends upon the quality and quantity of bait used besides the ground at which the traps are set. On account of the limitations in the naked diving, the traps are set only very near the shore at fairly shallow grounds.

While investigating the possibilities of improving the existing lobster gear and the present methods of fishing, it was felt that suitable gill nets, if properly designed, might perhaps substantially improve the catches. The design, fabrication and operation of gill nets are quite simple and different types of them are the most common fishing gear of the local fishermen (Balasubramanyan, 1958). Although gill nets are being used for lobster fishing in some areas, a closer examination of these nets revealed a poor design and the catches were consequently never remunerative. The Central Fisheries Technological Research Station at Cochin designed a simple bottom set gill net and conducted trial fishing at Muttom during December 1957 (Miyamoto and Shariff, 1958). The results in these initial trials were encouraging. However, it was found necessary to make some changes in the design and the construction of the net. Accordingly, changes in the quality of material used for the fabrication of the nets, the mesh size, the length-breadth proportion and the buoyancy of the nets were all effected and a number of new nets, both of nylon and cotton, were fabricated for further studies.

Descriptive Account of the New Design and Its Specification

As shown in Fig. 1 the net is of rectangular shape designed for setting at the bottom of the sea with cement sinkers attached to the foot-rope and

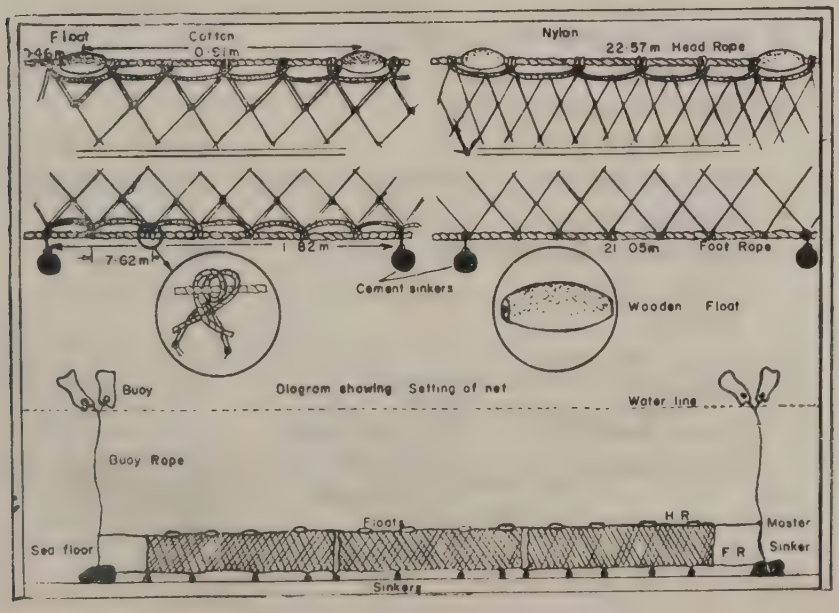

Fig. 1. Design diagram of bottom-set gill nets.

wooden floats attached to the head rope. One unit is made up of several 'shots' (pieces of webbing) numbering about 9 to 10. The details of specifications of the nylon and the cotton nets are given below:

	Cotton nets	*Nylon nets*
I. *Main webbing*:		
(1) Material ..	Cotton	Nylon
Count of Yarn	No. 20	No. 6
Ply and total yarns	3 ply; 12 yarns	..
Twist ..	Soft twist 2·9/cm. outer 1·2/cm. inner	..
Breaking strength ..	Dry 6·0 kg. Wet 7·4 kg.	Dry 23·2 kg. ..
Breaking stretch ..	Dry 22% Wet 16%	Dry 26·5% ..
(2) Kind of knot ..	Single trawl knot	Double trawl knot
(3) Size of mesh ..	15·24 cm. stretched condition	15·24 cm. stretched condition
(4) Number of meshes in length per shot	250	250
(5) Number of meshes in depth per shot	15	15
(6) Weight of each shot	2·205 kg. (average)	2·755 kg. (average)
(7) Percentage of take-up:		
Head-rope or float-line	46	46
Ground rope or lead-line	50	50
II. *Head rope or float-line*:		
Material ..	Sisal	Coir
Ply and diameter ..	3 ply and 4 mm.	..
Length required ..	22·57+0·46 m. extra on either side	22·57 m. and 0·46 m. extra on either side

		Cotton nets	*Nylon nets*
	Number of ropes required	1	2
	Breaking strength ..	72·5 kg. Dry	..
		76·8 kg. Wet	..
III.	*Foot-rope or lead-line*:		
	Material ..	Sisal	Coir
	Ply and diameter ..	3 ply, 6 mm.	Single ply, 2 mm.
	Total length required ..	21·05 m. and 0·46 m. extra on either side	21·25m. and 0·46m. extra on either side
	Number of ropes used ..	1	3
	Breaking strength ..	73·5 kg. Dry	..
		84·90 kg. Wet	..
IV.	*Lacing twine*:		
	Material	Cotton	Cotton
	Count, ply and total yarn	30/3/27	20/3/27
	Breaking strength ..	12·46 kg. Dry	12·46 kg. Dry
	..	12·45 kg. Wet	12·45 kg. Wet
V.	*Buoy rope*:		
	Material ..	Coir	Coir
	Diameter ..	1·92 cm.	1·92 cm.
	Length of rope ..	18·4 to 27·6 m.	18·4 to 27·6 m.
	Number of ropes ..	2	2
VI.	*Floats*:		
	Material ..	Wooden floats made of '*Elavu*' (*Bombax* sp.)	Same as in cotton nets
	Shape and diameter of centre bore ..	Spindle-shaped with 0·8 cm. bore	,, ,,

		Cotton nets	*Nylon nets*
	Dimensions ..	10·16 cm. length, 3·8 cm. breadth at the centre tapering to 2·54 cm. at the ends	Same as in cotton nets
	Buoyancy of each float	0·045 kg.	,, ,,
	Total floats used ..	23 numbers	,, ,,
	Total buoyancy ..	1·035 kg.	,, ,,
	Distance between each float	·91 m.	,, ,,
	End marker buoys:		
	Material ..	Wooden floats made of '*Elavu*' (*Bombax* sp.)	,, ,,
	Dimensions ..	·457 m. × ·152 m. × ·152 m.,—2–3 numbers	,, ,,
VII.	*Sinkers*		
	Material ..	Specially made cement sinkers	
	Shape ..	Convex disc with 6·35 cm. diameter	
	Average weight of each sinker	283·5 gm.	283·5 gm.
	Number used and total weight	10–15 2·84–4·36 kg.	10–15 2·84–4·36 kg.
	Distance between each sinker	1·50–1·84 m. apart	1·50–1·84 m. apart
	Master sinkers ..	Granite stones of 4·54–7·26 kg. each and 2–3 numbers	
VIII.	Net preservation ..	Dyed with 3% cutch solution	No preservative

Grounds Fished and Fishing Operations (Fig. 2)

With the gill nets fabricated as per the above specifications, the experimental fishing operations for lobsters were commenced on 2–2–1959 off Muttam, a coastal fishing village in the district of Kanyakumari, on the South-West Coast of India (Longitude E. 77° 19′ and Latitude N. 8° 7′).

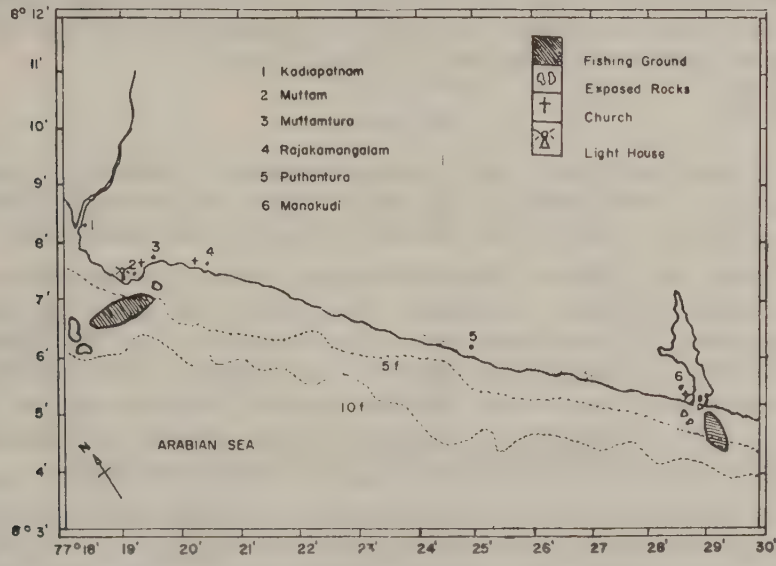

Fig. 2. Map showing the area of lobster fishing operations off Muttam and Manakudi along the South-West Coast of India.

This village is situated 12 miles from the district headquarters Nagerkoil and is easily approachable by road. There is a light house adjoining the sea-shore here. The coast contour at this area is very steep running down the sea with number of submerged and exposed rocks scattered all around. The sea at this location is generally calm with very mild breakers. The current close to the shore is always feeble with the water mostly clear. The place of fishing operation was the ground at depths ranging from 5–8 fathoms where the local fishermen also operate their various gear for lobsters. Initial operations were conducted with one unit of 3 nylon and 7 cotton shots of nets from small catamaran, the only local fishing craft. The nets were set late in the evenings at varying depths within a mile from the shore. They were kept overnight and were hauled the next morning. The operations were intensified substantially and a total of 32 to 40 shots were operated daily from 4 to 5 catamarans. The operations continued up to 13–2–1959.

The usual time taken for setting the nets was about 35 to 40 minutes for nearly 40 shots. Few trial fishings were also conducted off the neighbouring village Manakudi. Day to day catches were recorded separately both for cotton and nylon nets. Observations regarding weather conditions, phases of moon, size and weight of the catches were also recorded. Besides lobsters, miscellaneous fishes comprising of sharks, rays, cat-fishes, jew-fishes, thread-fins, etc., were also caught. The results of the experimental fishing operations are formulated in the form of Tables I and II.

Discussion

As seen from Tables I and II during the period of experimental fishing operations, a total quantity of 122 shots of nylon and 202 shots of cotton nets were used at Muttam and 30 shots of cotton nets at Manakudi.

During the 11 days of fishing at Muttam, a total number of 62 lobsters were caught. Of these, 34 numbers were caught in the nylon nets while the remaining 28 on the cotton nets. Apart from lobsters, a total quantity of 451·56 kg. of miscellaneous fishes were also caught by these nets during the above operations of which 365·60 kg. were by the nylon nets and the remaining by the cotton nets. During the 3 days of fishing at Manakudi, a total number of 17 lobsters and 4·81 kg. of fishes were caught.

In gill nets, the catch may be considered to be proportional to the area of the net under operation. The larger the net, the greater is the area of operation and consequently more of catch. Assuming 'a' as the mesh size under stretched condition, 'n' as the number of meshes in length in each shot and 'n_1' as the number of meshes in depth in each shot; then,

$$A = \{an\,(1 - S)\,xan_1 \times \sqrt{2S - S^2}\} \times N$$

where 'A' is the area of the shots operated and 'S' is the ratio of take-up and 'N' the total number of shots used.

Therefore, the catch per unit area of the net 'C_1' may be represented as $C_1 = (C/A)$ where 'C' is the total catch.

In the case of the nets under discussion $a = 15{\cdot}24$ cm., $n = 250$ meshes, $n_1 = 15$ meshes and $S = 0{\cdot}5$.

Therefore, the area of one shot is 37·566 sq. m. The total area of nets operated during the entire period of experimental fishing is 4584·997 sq. m. for nylon, 7588·419 sq. m. for cotton at Muttam and 1126·956 sq. m. for cotton at Manakudi.

Taking 9·281 sq.m. as unit area of net per operation, then the ratio of catch-per-unit area 'C_1' is calculated by:

$$C_1 = \left\{\frac{C}{\text{Total area of webbing}}\right\} \times 9{\cdot}28^{1}.$$

The values of C_1 derived from the above for the present series are given below:

	For lobster (kg.)	*For fish* (kg.)	*Total* (kg.)
At Muttam:			
Nylon net ..	0·025	0·743	0·768
Cotton net ..	0·011	0·105	0·116
At Manakudi:			
Cotton net ..	0·047	0·038	0·085

It would be seen from the above that the efficiency of both nylon and cotton nets in catching lobsters appears to be more or less the same whereas nylon nets have landed more fishes (nearly 7 to 8 times) than cotton nets. The number of lobsters caught with cotton nets at Manakudi are greater than those caught with cotton nets at Muttam. This may perhaps be due to the richness of the fishing ground at Manakudi. During one of the operations at Manakudi, few pieces of mussel meat were left tied to the webbings of the net just to see whether this could lure the lobsters. Though the result seems to be quite satisfactory, further experiments may be necessary in this direction (Table II).

Thyagarajan (1958) at Tuticorin has worked out the catch of fish per 100 sq. ft. of both nylon and cotton nets (*Pachu valai*—Tamil) as 0·50 kg. and 0·34 kg. respectively. These figures are quite comparable to those obtained at Muttam and Manakudi. It is worth mentioning here that the local fishermen did not operate lines and anchor hooks for catching lobsters at the time of the above investigations. However, some fishermen were tending traps for lobsters at selected grounds. As only few traps were operated and as the catches were meagre, it was not possible to compare their catch with those of the new design of net to work out the relative efficiency of each gear. It can be stated that when conditions are not ideal

TABLE I

Data showing catch of lobsters and fish obtained during the experimental fishing operations at Muttam with bottom-set gill nets during 2–2–1959 *to* 14–2–1959

Date	Depth at fishing ground (metres)	No. of shots		Catch					
				Lobsters				Fish	
				Nylon		Cotton		Nylon	Cotton
		Nylon	Cotton	No.	Wt. in kg.	No.	Wt. in kg.	Wt. in kg.	Wt. in kg.
(*a*) 2–2–1959 (*b*) 3–2–1959	11·04	3	7	..	..	..	..	10·89	11·79
(*a*) 3–2–1959 (*b*) 4–2–1959	11·04	3	7	..	..	..	..	14·52	9·53
(*a*) 4–2–1959 (*b*) 5–2–1959	9·20–11·04	9	15	1	0·23	..	..	57·61	4·76
(*a*) 5–2–1959 (*b*) 6–2–1959	7·36–12·88	12	20	3	0·79	3	1·25	58·29	8·62
(*a*) 6·2–1959 (*b*) 7–2–1959	7·36–14·72	15	25	..	..	1	0·11	42·18	4·99

(*a*) 8–2–1959 (*b*) 9–2–1959	7·36–14·72	15	25	..	..	1	0·34	28·35	10·43
(*a*) 9–2–1959 (*b*) 10–2–1959	7·36–9·20	12	20	2	1·39	4	1·59	52·39	9·07
(*a*) 10–2–1959 (*b*) 11–2–1959	11·04	13	21	4	2·04	2	0·91	23·02	3·18
(*a*) 11–2–1959 (*b*) 12–2–1959	9·20–14·72	13	21	10	3·40	6	2·04	25·06	7·71
(*a*) 12–2–1959 (*b*) 13–2–1959	11·04–14·72	13	21	13	4·87	8	2·15	36·51	3·63
(*a*) 13–2–1959 (*b*) 14–2–1959	11·04–14·72	14	20	1	0·23	3	1·13	16·78	12·25
	TOTAL ..	122	202	34	12·69	28	9·52	365·60	85·96
	Catch per shot	..	..	0·280	0·104	0·140	0·047	2·99	0·425
Catch per 100 sq. ft. (9·281 sq. m.) of webbing		..	..	..	0·025	..	0·011	0·743	0·105

a, Nets laid. *b*, Nets hauled.

* New-moon.

TABLE II

Showing the data of catch obtained from bottom-set gill nets at Manakudi

Date and time of operation	Depth at fishing ground (metres)	No. of cotton shots operated	No. of lobsters caught	Wt. of lobsters caught (kg.)	Wt. of fish caught (kg.)	Remarks
(*a*) 19-2-1959—17·30–18·3 (*b*) 20-2-1959—6·30–7·30	3·68–9·20	10	1	0·45	1·18	No bait
(*a*) 20-2-1959—17·30–18·30 (*b*) 21-2-1959—6·30–7·30	5·52–11·04	10	11	3·63	1·81	*Mussel bait was used. The meat was tied in lumps along the webbing in a scattered way
(*a*) 1-3-1959 18·00–19·10 (*b*) 2-3-1959—7·00–8·00	3·68–9·20	10	5	1·64	1·81	No-bait
Total catch		30	17	5·72	4·80	..
Catch per shot		..	0·57	0·19	0·16	..
Catch per 100 sq. ft. (9·281 sq. metres) of webbing	..	..	..	0·047	0·038	..

a, Nets laid; *b*, Nets hauled.

* Use of Mussel bait in the gill net is a novel experiment which has yielded some good results.

for the fishermen to operate the existing lobster gear, the new design of net could be operated with advantage. The method of catching both lobsters and fishes together with bottom-set gill net is always remunerative than gears operated exclusively for lobsters. The new design is simple and the fabrication is quite easy which does not require any special technique for operation. Either cotton or nylon can be used for the fabrication depending on their availability. A the quantity of material required for the webbing is only very little, fishermen can easily afford to take to this new design with very little investment. The setting of these gill nets is also very simple and quick.

There is no need for baits and no need for diving while operating this net. Even with the existing type of sailing craft, the area of operation for lobster fishing could easily be extended and intensified. Lobsters that abound the deeper waters can also be fished by these gill nets whereas setting of traps for them at greater depths becomes an impossible task as long as diving is resorted to.

During the coming season it has been programmed to conduct a series of fishing experiments with these nets at different depths both in inshore and offshore areas to assess the maximum efficiency of the new design. Once the design proves a success, it is bound to improve the existing method of fishing.

Summary

Considering the vast resources for lobsters in India, their fishery can be organised in a better way than at present. The demand for Indian lobsters in the foreign markets has given a new status for the lobster fishing industry in India.

There exists an important fishery for lobsters along the South-West Coast of India. Traps, anchor hooks and scoop nets are the existing fishing gears employed for lobster fishing in this area. The present fishing is restricted to limited areas only.

With a view to improving the existing lobster fishing and to extend the present area of operation, simple yet efficient fishing gear was designed at the Central Fisheries Technological Research Station at Cochin. In order to assess the working efficiency of the new design, preliminary experimental fishing were conducted at Muttam and Manakudi, two important centres for lobster fishing along the South-West Coast of India.

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FIGS. 1–4. Fig. 1. Preparing for the day's fishing. Fig. 2. The Catch—Lobsters and Rays. Fig. 3. The Catch—Miscellaneous fishes. Fig. 4. A full-sized Lobster.

SOME MEASUREMENTS OF TOXICITY OF TANNERY AND TEXTILE WASTES AND THEIR COMPONENTS TO FISH BY BIO-ASSAYS

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Introduction

It is only in recent years that attempts have been made to study effects of industrial wastes on the riverine fish resources in India and correctly assess the damage. With an accelerating increase presently in various fields of industrial development, the practice by the factories to dispose the trade wastes and effluents into the nearest stream or river without considering its consequences, will become still more widely prevalent. Every water-shed has its own pollutional load-bearing capacity and if within limits, the river or stream is able to render innocuous the adverse effects by physical, chemical and biological purificatory processes and thus maintain the aquatic life of a stream or river causing no obvious damage. If, however, pollutants are added in large quantities they may seriously alter the environmental conditions for a certain stretch, and the waste may thus affect fish life. Besides a study of the physico-chemical and biological conditions of the affected stream to evaluate the harmful effects to fish life indirectly, direct experimental evidence is also necessary to ascertain how and in what concentrations such effluents or their constituents kill the fish. By the application of methods of bio-assay, a biologist can easily measure the degree of toxicity in a material and to what extent it should be diluted or otherwise treated before being added to a stream. Thereby, precise standards for the disposal of each individual industrial waste can be set up more scientifically. Such dilutions will be favourable not only to fish but also for fish food organisms which find suitable medium to grow and reproduce and provide an optimum fishcrop.

Pioneering work in this field has been done by Shelford, Blending, Carpenter and Ellis, and improved by Hart, Doudoroff and Greenback (1945). It is now made simple and applicable to most practical problems which can be used in a number of ways by various public agencies or by the industries themselves, to control the factory wastes.

During the course of a pollution study of the river Ganga at Kanpur where a large number of factories, mainly textile mills and leather tanneries are situated, parallel bio-assay experiments were undertaken on several types of wastes liquors, results of which form the basis of the present communication.

Method and Materials

The experiments were conducted in 10 litre capacity cylindrical battery jars (40×28 cm.). The diluent used was ordinary tap-water stored previously in an open reservoir for removing chlorine if any, in the water. The dilution of the liquor was made on a logarithmic scale soon after it was brought to the laboratory from the tannery or textile mill. Burdick *et al.* (1955) during the course of their bio-assay experiments on the toxicity of rotenone to fish observed, that time of death of experimental fish is logarithmically distributed if they are expressed in logarithms of actual arithmetical values.

The test fish used in these experiments were collected locally from unpolluted ponds and inundated river banks. They were brought with care to the laboratory and stored in large earthen containers and acclimatised for four days. Feeding by natural plankton and other food was suspended two days before the experiments.

The species initially selected was *Cirrhina mrigala* but later, due to non-availability of required size of this important commercial species, the smaller *Puntius sophore* and *Mystus vittatus* were selected. These two species represent a very common minorcarp and a small cat-fish, ideally suited because of their sizes and distributed all over India and hence easily available for such experiments.* These test animals were removed one by one from earthen containers by a handnet and after careful examination (free from disease and damage or abnormalities of appearance or of behaviour) kept in small cylindrical jars in required numbers. Care was taken to prevent each fish from jumping or otherwise harming itself.

Ten fishes were used in each jar with a control and observations continued for a period of 24 hours. A fish was considered to be dead when with a slight prod by rod, it failed to respond. Such a fish was taken out of the jar and preserved in formalin for measurements. The activities of the fish such as swimming movements, breathing, mode of distress and death were noted throughout the period of observation. Such experiments

* *P. sophore* is ideally suited for such experiments similar to the goldfish—*Carassius carassius*, used for bio-assay in other countries. Toxicity experiments can hereafter be based upon the sensitivity of this fish, results being expressed as such in Indian conditions.

were conducted during September, December and May months to observe if any seasonal changes are noticeable in lethal concentrations. As no thermostatic arrangement for controlling temperature was procurable, effort was made to minimise the high range of temperature during the hot summer month of May, by wrapping each jar with a thick cloth and keeping it constantly wet. This arrangement had the desired effect, the temperature maintained in the jars being comparable with the temperature of the river water at the time. During winter no arrangements were necessary for temperature control. Prior to the start of full-scale experiments, simple exploratory tests over a wide range of dilutions of the wastes of completely unknown toxicity were performed in 4-litre cylindrical battery jars. Since all the liquors except the bleach liquor had high oxygen demand, the diluent water was first oxygenated directly from oxygen cylinders in such a way, that as the required quantity of liquor was added, the supersaturated oxygen level after satisfying the high demand, always left a budget of 5–8 ppm. of oxygen. The test animals were then introduced. From time to time loss of dissolved oxygen below the above level if any caused by the test animal, was made good by slow diffusion of oxygen taking special care that little or no loss of volatile components was caused. Bleach liquor was not disturbed by oxygenation as it had initially sufficient oxygen budget which did not decrease to a low level to warrant oxygen diffusion. Since similar wastes may vary widely in different streams because of the original water quality, the dilution water was previously analysed for pH, alkalinity and hardness, which showed the following values:

	pH	Alkalinity	Hardness
September ..	7·9	80	46
December ..	8·0	172	126
May ..	8·0	196	140

The fish in different liquors behaved differently and died at varying intervals. Results obtained were plotted on graph papers. The median tolerance limit, TLm, was obtained by means of a straight line graphical interpolation, reading directly from the graph where the line crosses the 50% survival line (Doudoroff *et al.*, 1951) as in Figs. 1 and 2.

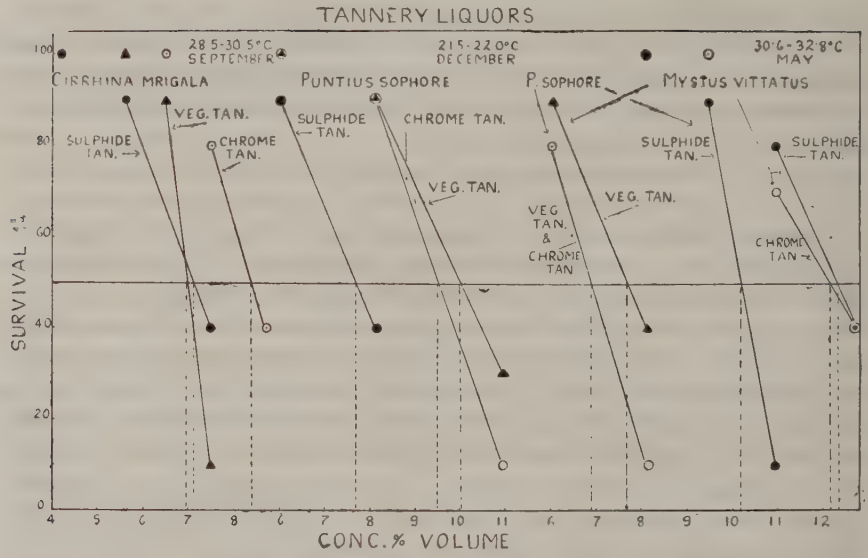

FIG. 1. Showing the median tolerance limit (TLm) of fish in tannery wastes by the straight line graphical interpolation method at 50% survival line.

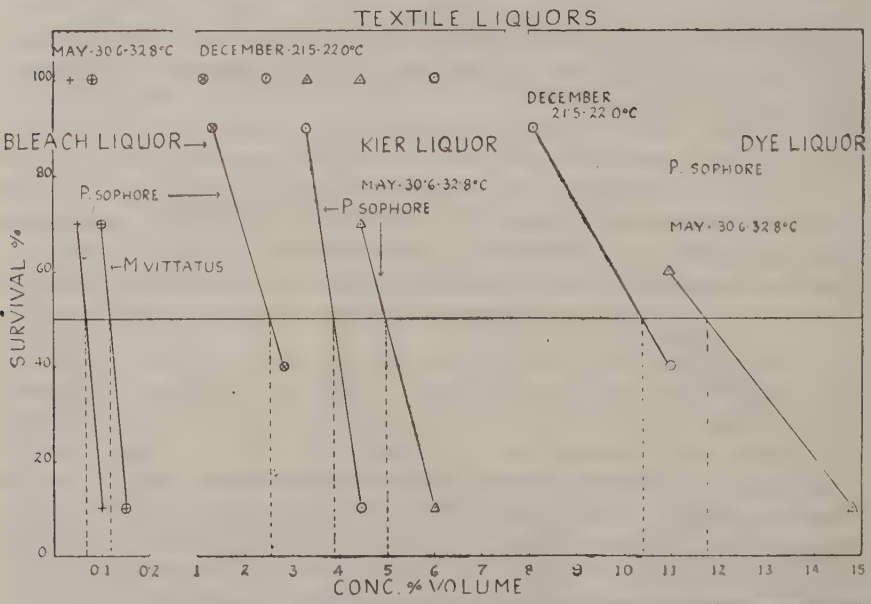

FIG. 2. Showing the median tolerance limits (TLm) of fish in textile wastes by the straight line graphical interpolation method at 50% survival line.

Nature and Composition of Different Liquors

Tannery.—There are two main types of waste waters produced in tanneries, namely:

(*a*) Liquors resulting from soaking, liming and deliming of skins termed "beam-house" wastes. These are alkaline, grossly polluting liquids containing organic matter, hair, lime, sulphide and a high proportion of ammoniacal nitrogen and organic nitrogen.

(*b*) Somewhat acidic, highly coloured, spent tanning liquors known as "tanyard" wastes whose composition depends upon the method of tanning employed. Vegetable tanning wastes contain more polluting organic matter than do chrome tanning wastes but the latter are more difficult to treat by biological processes on account of the presence of inhibitory chromium compounds. This is why before allowing the wastes into sewers, chromium is usually precipitated in a catch-pit by the lime liquor obtained directly from the lime house.

Textiles.—The processes as adapted in the cotton textiles are mainly deterging (kiering), bleaching, miscellaneous operations and finally dyeing and printing.

Deterging or kiering wastes are the strongest of all wastes from textile mills as they are highly alkaline containing large amounts of vegetable fat, putrescible organic matters from raw fibres, etc.; chlorine is present in bleach liquor; soda ash, caustic soda, resin soap, impurities of cotton, wax, sizing materials, etc., are thrown out during miscellaneous operations and organic dyes in strongly alkaline water in dyeing and printing.

It is seen from the above that three factors dominate textile waste liquors, one is highly alkaline, second is rich in organic matter because of the presence of different organic dyes in large quantities and finally chlorine dominates in the form of calcium hypochlorite in the bleach liquor. Results of analysis of chrome, vegetable and sulphide tan liquors and kier, dye and bleach liquors are given in Table I. Standard Methods of A.P.H.A. (1955) were followed throughout for the collection, preservation and analysis of samples.

Experimental Results

The experiments were conducted on three different tannery liquors, *i.e.*, chrome tan liquor, sulphide tan liquor and vegetable tan liquor, three textile wastes, *i.e.*, kier, dye and bleach liquors. The results of 24 hours observations are given in Tables III and IV.

TABLE I

Results of physico-chemical analysis of crude tannery and textile wastes showing ranges of various constituents

Type of waste water	Appearance	pH	Transparency		Oxygen absorbed		Total solids	Total diss. solids	Total suspended solids
			settled ppm.	shaken ppm.	3 mts. at 27° C.	30 mts. at 100° C.			
Vegetable tan liq. ..	Light brown	7·5–8·0	700 to 3000	1600 to 5800	690 to 1460	3050 to 6480	11580–21992	9465–18604	2115–3388
Sulphide tan liq. ..	do.	8·1–8·7	150 to 400	800 to 1200	128 to 450	678 to 2400	9304–15356	8667–13604	637–1752
Chrome tan. liq. ..	Light greenish	8·1–9·5	230 to 250	330 to 1000	58 to 510	152 to 1720	13188–13968	12036–12951	1017–1152
Kier liq. ..	Brown	8·0–9·6	390 to 900	800 to 1300	590 to 743	3440 to 4950	8896–19328	6992–15533	1904–3795
Dye liq. ..	Deep green	>9·6	1200 to 3000	1500 to 5000	295 to 680	1400 to 4280	4248–23800	3576–20701	672–3099
Bleach liq. ..	Light milky	7·9–9·6	Nil	100 to 270	..	17 to 20	1068–3948	1028–3884	40–64

TABLE I (*Contd.*)

Type of waste water	Loss on ignition	Total fixed solids	Total alkalinity (as $CaCO_3$)			Nitrogen		Total sulphide as (s)	Free chlorine	5-day B O.D.
			(CO_3)	(OH)	(HCO_3)	Amm. N.	Alb. N.			
Vegetable tan. liq. ..	2552–3828	9328–18164	..	..	2400–2700	66·7 to 154	22·2 to 32	559–1363	..	3570–4800
Sulphide tan. liq. ..	531–1584	8773–13772	0–800	..	900–1440	66·7 to 133	33·3 to 67	138–596	..	635–1029
Chrome tan. liq. ..	1733–1868	11320–12235	0–1800	..	700–900	30·5 to 133	66·8 to 71	109–596	..	610–1114
Kier liq. ..	1356–3250	7540–16078	0–5200	..	1600–6600	5 to 133	13·3 to 24	554–950	..	2450–3920
Dye liq. ..	260–2687	3988–21113	0–2800	0–500	300–2600	7·2 to 16·1	9·1 to 25·9	979–1250	..	7272–9290
Bleach liq. ..	308–332	760–3616	0–880	0–60	0–200	..	..	..	127–141	..

The results are expressed in ppm.

TABLE II

Showing percentage of survival and median tolerance limit of some test fish in various liquors of tannery wastes in different seasons

Months	Nature of liq.	Range of temp. °C.	Conc. of liq. used in p.c. (Vol.)	Survival No.	Percentage of survival	Median tolerance limit	Test fish used	Size (mm.)			Weight (gm.)		
								Max.	Min.	Av.	Max.	Min.	Av.
September ..	Chrome tan. liq.	28·5 to 30·5	4·9	10	100	8·38	*C. mrigala*	60	29	44·1	2·0	0·3	0·92
			6·5	10	100			52	34	44·0	1·3	0·4	0·76
			7·5	8	80			51	29	38·5	1·4	0·3	0·67
			8·7	4	40			59	28	42·2	1·4	0·3	0·71
			10·0	Nil	Nil			52	31	40·1	1·3	0·4	0·67
			Control	10	100			53	30	39·6	1·4	0·3	0·67
do. ..	Sulphide tan. liq.	28·5 to 30·5	3·2	10	100	7·13	do.	52	28	36·7	1·3	0·4	0·67
			4·2	10	100			50	28	35·3	6·4	0·3	0·64
			5·6	9	90			53	28	37·4	2·8	0·4	0·78
			7·5	4	40			54	29	36·7	1·4	0·4	0·67
			8·7	Nil	Nil			50	24	35·7	1·5	0·5	0·58
			Control	10	100			51	29	36·2	1·3	0·3	0·64
do. ..	Vegetable tan. liq.	28·5 to 30·5	4·9	10	100	7·0	do.	60	29	44·1	2·0	0·3	0·98
			5·6	10	100			49	32	40·9	1·1	0·2	0·66
			6·5	9	90			51	33	43·7	1·5	0·4	0·82
			7·5	1	10			45	36	40·6	1·0	0·4	0·61
			8·7	Nil	Nil			47	38	43·3	1·1	0·5	0·69
			Control	10	100			49	30	39·4	1·1	0·3	0·67
December ..	Chrome tan. liq.	21·5 to 22·0	4·47	10	100	9·55	*P. sophore*	53	45	48·0	2·1	1·1	1·60
			6·03	10	100			56	42	47·0	2·5	1·1	1·40
			8·14	9	90			58	42	50·0	3·1	0·8	1·70
			10·98	1	10			54	43	47·0	2·0	1·0	1·40
			14·82	Nil	Nil			60	41	49·0	3·2	0·9	1·60
			Control	10	100			58	41	50·0	3·0	0·8	1·60
do. ..	Sulphide tan. liq.	21·5 to 22·0	2·85	10	100	7·7	do.	68	40	49·1	3·2	0·9	1·61
			4·47	10	100			54	41	48·0	2·3	1·0	1·40
			6·03	9	90			53	37	45·0	2·3	0·7	1·30
			8·14	4	40			62	40	49·0	3·4	0·8	1·60
			10·98	Nil	Nil			64	38	44·0	3·8	0·8	1·70
			Control	10	100			54	40	48·0	2·3	0·9	1·50
do. ..	Vegetable tan. liq.	21·5 to 22·0	4·47	10	100	10·03	do.	59	45	52·0	3·6	0·7	1·8
			6·03	10	100			63	40	51·0	3·5	0·7	1·8
			8·14	9	90			64	46	53·0	3·3	0·7	1·8
			10·98	3	30			67	45	54·0	4·0	1·3	2·2
			14·82	Nil	Nil			60	50	54·0	2·7	1·4	2·05
			Control	10	100			64	45	53·0	3·2	0·8	1·8

May ..	Chrome tan. liq.	30·6 to 32·8	3·31	10	100	6·9	do.	86	52	73·6	9·2	3·0	7·0
			4·47	10	100			85	50	73·3	9·4	2·7	6·1
			6·03	8	80			85	66	73·8	8·2	3·8	5·8
			8·14	1	10			98	65	79·9	13·5	3·8	7·5
			9·45	Nil	Nil			85	61	74·6	8·5	3·2	5·98
			Control	10	100			60	50	54·0	2·8	1·4	2·0
do. ..	Sulphide tan. liq.	30·6 to 32·8	4·47	10	100	10·2	do.	94	64	32·0	9·0	3·3	5·00
			6·03	10	100			85	69	77·2	5·5	3·1	5·00
			8·14	10	100			77	65	70·0	5·1	3·0	4·00
			9·45	9	90			83	63	68·6	7·3	3·3	4·8
			10·98	1	10			81	58	71·8	6·8	2·0	4·92
			14·82	Nil	Nil			85	64	73·0	7·3	3·0	4·8
			Control	10	100			76	55	70·5	7·0	2·8	4·91
do. ..	Vegetable tan. liq.	30·6 to 32·8	2·46	10	100	6·9	do.	85	65	74·0	5·5	3·1	4·28
			3·32	10	100			75	52	63·6	6·7	1·9	3·93
			4·47	10	100			85	50	65·4	9·6	2·2	4·83
			6·03	8	80			85	70	77·0	5·6	3·3	4·73
			8·14	1	10			95	65	83·2	10·0	3·1	6·72
			9·45	Nil	Nil			77	65	71·6	4·7	3·0	3·74
			Control	10	100			95	62	72·8	9·5	2·7	4·42
do. ..	Chrome tan. liq.	30·6 to 32·8	7·00	10	100	12·18	*M. vittatus*	78	65	71·0	4·9	2·9	3·80
			8·14	10	100			85	70	77·0	5·6	3·3	4·70
			9·45	10	100			90	64	75·2	7·1	2·2	4·19
			10·98	7	70			85	65	75·4	7·3	2·7	4·56
			12·76	4	40			78	65	70·8	4·6	2·6	3·21
			14·82	Nil	Nil			86	64	75·2	7·2	2·5	4·50
			Control	10	100			85	63	70·9	7·3	2·6	3·32
do. ..	Sulphide tan. liq.	30·6 to 32·8	6·03	10	100	12·33	do.	78	65	70·1	4·5	2·5	3·20
			8·14	10	100			78	60	67·3	4·5	2·5	3·3
			10·98	8	80			95	70	78·5	8·8	2·7	4·8
			12·76	4	40			83	72	76·9	5·4	2·8	3·89
			14·82	Nil	Nil			85	64	73·0	5·5	3·0	4·0
			Control	10	100			85	71	77·2	5·6	3·0	4·7
do. ..	Vegetable tan. liq.	30·6 to 32·8	3·31	10	100	7·7	do.	85	65	74·0	5·5	3·1	4·28
			4·47	10	100			77	65	71·6	4·7	3·0	3·74
			6·03	9	90			85	70	77·0	5·6	3·3	4·73
			8·14	4	40			95	65	83·2	10·0	3·1	6·72
			10·98	Nil	Nil			95	62	72·8	9·5	2·7	4·42
			Control	10	100			78	65	71·0	4·9	2·9	3·80

TABLE

Showing percentage of survival and median tolerance limit of some

Months	Nature of liq.	Range of temperature ° C.	Conc. of liq. used in p.c. (Vol.)	Survival No.	Percentage of survival
December ..	Kier liq.	21·5 to 22·0	2·46	10	100
			3·32	9	90
			4·47	1	10
			6·03	Nil	Nil
			Control	10	100
do. ..	Dye liq.	21·5 to 22·0	1·35	10	100
			2·85	10	100
			4·47	10	100
			6·03	10	100
			8·14	9	90
			10·98	4	40
			14·82	Nil	Nil
			Control	10	100
do. ..	Bleach liq.	21·5 to 22·0	1·16	10	100
			1·35	9	90
			2·85	4	40
			4·47	Nil	Nil
			Control	10	100
May ..	Kier liq.	30·6 to 32·8	2·46	10	100
			3·32	10	100
			4·47	7	70
			6·03	1	10
			8·14	Nil	Nil
			Control	10	100
do. ..	Dye liq.	30·6 to 32·8	2·46	10	100
			3·32	10	100
			4·47	10	100
			10·98	6	60
			14·82	1	10
			17·21	Nil	Nil
			Control	10	100
do. ..	Bleach liq.	30·6 to 32·8	0·035	10	100
			0·050	7	70
			0·100	1	10
			..	Nil	Nil
			Control	10	100
do. ..	do.	30·6 to 32·8	0·067	10	100
			0·082	10	100
			0·100	7	70
			0·150	1	10
			..	Nil	Nil
			Control	10	100

III

test fish in various liquors of textile wastes in different seasons

Median tolerance limit	Test fish used	Size (mm.)			Weight (gm.)		
		Maximum	Minimum	Average	Maximum	Minimum	Average
3·9	*P. sophore*	58	45	49	3·0	1·2	1·7
		61	23	47	3·2	1·1	2·9
		60	55	51	2·9	1·5	2·1
		60	43	51	2·7	1·0	1·6
		62	47	54	3·5	1·2	2·1
10·45	do.	57	43	52	2·9	1·3	2·0
		62	40	49	3·8	0·9	1·8
		60	39	50	3·2	1·0	2·0
		56	45	49	2·4	1·3	1·7
		57	45	51	2·5	1·2	1·8
		61	45	51	3·3	1·2	1·8
		57	40	50	2·3	0·8	1·8
		57	40	49	2·4	0·7	1·5
2·55	do.	61	42	56	3·2	1·0	2·2
		60	45	51	2·9	1·2	1·8
		61	44	52	3·5	1·2	2·2
		65	47	54	3·7	1·5	2·1
		60	44	53	3·3	1·0	2·1
5·0	do.	82	62	70	6·8	3·5	4·8
		86	60	69	6·0	3·3	4·8
		80	62	68·8	5·9	3·4	4·78
		82	62	70·6	7·6	3·7	5·21
		82	65	71·4	8·4	3·4	5·72
		82	61	70·0	6·8	3·3	4·60
11·75	do.	85	65	60·0	8·1	2·9	5·17
		85	55	67·9	9·5	2·4	4·95
		85	52	68·7	8·7	2·3	4·41
		78	59	68·8	7·2	2·9	5·96
		85	68	79·8	9·5	4·3	6·41
		85	54	67·0	9·4	2·8	5·8
		79	55	69·4	6·5	2·4	4·49
0·07	do.	90	58	76·4	11·7	2·3	6·6
		82	58	70·2	7·9	3·0	5·47
		93	63	73·4	12·4	2·3	6·21
		85	58	73·2	10·9	3·5	5·45
		106	60	77·1	18·1	3·1	7·60
0·11	*M. vittatus*	87	66	77·2	7·0	3·0	4·48
		103	53	77·0	17·5	1·1	6·45
		93	70	77·5	7·1	2·7	4·13
		80	65	71·3	6·4	3·3	4·2
		89	62	73·8	6·4	3·4	4·48
		91	60	78·0	7·0	2·9	5·70

TABLE IV

Showing tests of significance applied to survival rates in different months with different liquors

x = Concentration; y = Survival; A. Liquor: Chrome tan; Test animal: *P. sophore.*

Source of variation	D.F.	Sxy*	Sx^2Sy^2	S.S.	D.F.	M.S.
Total sets 7 ..	−56·91	44·29	111·87	38·74	6	..
Between expts. 1 ..	0·96	7·36	0·12	..	..	..
Within expts. 6 ..	−57·87	36·93	111·75	21·07	5	4·21
F = 17·67/4·21 = 4·197			..	17·67	1	17·67

Difference in survival rates in different seasons (December and May) are not significant at 5% level.

B. Liquor: Sulphide tan; Test animal: *P. sophore.*

Source of variation	D.F.	Sxy*	Sx^2Sy^2	S.S.	D.F.	M.S.
Total sets 8 ..	−48·75	55·69	86·89	32·83	7	..
Between expts. 1 ..	− 1·36	13·25	0·14	..	..	..
Within expts. 7 ..	−47·39	42·44	86·75	27·58	6	4·597
F = 5·15/4·597 = 1·12			..	5·15	1	5·15

Difference in survival rates in different seasons are not significant at 5 % level.

C. Liquor: Vegetable tan; Test animal: *P. sophore.*

Source of variation	D.F.	Sxy*	Sx^2Sy^2	S.S.	D.F.	M.S.
Total sets 8 ..	−56·24	58·36	94·89	40·69	7	..
Between expts. 1 ..	1·12	14·13	0·9	..	..	..
Within expts. 7 ..	−57·36	44·23	93·99	19·60	6	3·27
F = 21·09/3·27 = 6·4495			..	21·09	1	21·09

Difference in survival rates in different seasons are significant at 5% level but not significant at 1 per cent. level.

* Snedecor's notation mentioned in the book *Statistical Methods*, by G. W. Snedecor, Iowa State College Press, Iowa, 4th edition, 1950, was used.

A. Liquor: Kier; Test animal: *P. sophore.*

Source of variation	D.F.	S*xy*	Sx^2Sy^2	S.S.	D.F.	M.S.
Total sets 6 ..	— 27·85	9·92	102·86	24·67	5	..
Between expts. 1	0·37	0·73	0·19	..	..	..
Within expts. 5 ..	— 28·22	9·19	102·67	15·82	4	3·96
F = 8·85/3·96 = 2·235			..	8·85	1	8·85

Difference in survival rates in different seasons are not significant at 5% level.

B. Liquor: Dye; Test animal: *P. sophore.*

Source of variation	D.F.	S*xy*	Sx^2Sy^2	S.S.	D.F.	M.S.
Total sets 10 ..	—124·24	211·59	97·64	24·64	9	..
Between expts. 1	6·15	31·66	5·61	..	..	..
Within expts. 9 ..	—118·09	179·93	92·03	14·53	8	1·82
F = 10·11/1·82 = 5·555			..	10·11	1	10·11

Difference in survival rates in different seasons are significant at 5% level but not significant at 1% level.

C. Liquor: Bleach; Test animal: *P. sophore.*

Source of variation	D.F.	S*xy*	Sx^2Sy^2	S.S.	D.F.	M.S.
Total sets 5 ..	— 1·98	6·17	66·83	66·19	4	..
Between expts. 1	4·27	4·46	4·16	..	..	..
Within expts. 4 ..	— 6·25	1·71	62·67	43·83	3	14·61
F = 22·36/14·61 = 1·505			..	22·36	1	22·36

Difference in survival rates in different seasons are not significant at 5% level.

(i) *Observed Fish Behaviour.*—In vegetable tan liquor at high concentrations of 8·7%, *P. sophore* showed quick almost vibratory gill movements and had signs of distress. Within 15 minutes, two fish lost balance and overturned. The fish moved about with obvious discomfort, alternately losing equilibrium and recovering for a while. First complete mortality occurred in 45 minutes, and six fish died within two hours, all ten fish succumbing within five hours. Such distress and mortality was comparatively slow in its onset, even though rapid gill movements was a feature common at all concentrations, including 4·9%. Both *P. sophore* and *Mystus vittatus* behaved similarly in vegetable tannery liquor during all observations.

In sulphide tan liquors at higher concentrations *P. sophore* and *M. vittatus* first made an attempt to jump but later began to gasp heavily, with laborous breathing movements, and lost their sense of balance and later remained swimming in a slanting manner at an angle of 45-55°, head downwards. They however died gradually, opercular movements beginning to slow down by degrees.

In chrome tan liquor, the fish made quick jumping movements but did not lose their balance till the last moment of death, which was all too sudden. Except for faster gill movements as compared to fish in the 'control', the fish appeared almost normal till death overcame them.

In kier liquor, the fish showed distress by flitting almost at once when introduced, and came to the surface trying to gulp air after some time. The mucus coagulated and formed fluffy strands around the mouth, gills, eyes and fins, greatly impeding swimming movements of the fish. At a later stage, capillaries began to swell at the bases of the fins and lining of the mouth, as indicated by red patches. One peculiarity observed was that, in spite of there being over 5·00 ppm. of dissolved oxygen in the medium, the fish moved at the surface gulping air as if to supplement a deficiency oxygen. This was probably due to the inability of the gills to absorb sufficient oxygen by the removal of mucus and consequent swelling and bursting of the capillaries caused by an asphyxiation of the fish, compelling them to come to the surface.

In the dye liquor the fish died similarly as in kier liquor, with the coagulation of mucus, chokage and paralysis of gill movements. Gills gradually swelled probably due to a deposition of coagulated material, and actually burst in several instances. Fin bases and lining of the mouth also showed pink colouration.

In bleach liquor, at all tested concentrations, the fish remained at the bottom after an initial attempt at escape with fast gill movements, and died

at the bottom without showing obvious distress. The gill movements became feeble during later stages. The fish seemed to die as if slowly paralysed.

(ii) *Toxic Ranges.*—The results obtained during the present series of observations are for three ranges of temperature in different seasons with two to three species of test fish, *i.e.*, 28·5–30·5° C. in September with *C. mrigala*, 21·5–22·0° C. in December with *P sophore* and finally 30·6–32·8° C. in May with *P. sophore* and *M. vittatus*. The median tolerance limits from the above results for *C. mrigala* during September were 8·38%, 7·13% and 7·0% respectively for the chrome, sulphide and vegetable tan liquors. The average sizes of the fish were 49·70 mm., 36·30 mm. and 42·00 mm. in total length with average corresponding weights of 0·88 gm., 0·66 gm. and 0·73 gm. In December with *P. sophore*, whose average sizes were 48·5 mm., 47·18 mm. and 52·8 mm. in total length with average corresponding weights of 1·55 gm., 1·52 gm. and 1·9 gm., the respective concentrations being 9·55%, 7·7% and 10·03%. During May they were 6·9%, 10·2% and 6·9% respectively when the average sizes were 71·53 mm., 66·16 mm. and 72·51 mm. total in length with corresponding weights of 5·73 gm., 4·78 gm. and 4·66 gm.

In the textile wastes such as kier, dye and bleach liquors the median tolerance limit of *P. sophore* in December was 3·9%, 10·45% and 2·55% respectively when the average sizes of fish were 50·4 mm., 50·12 mm. and 53·2 mm. in total length with corresponding weights of 2·1 gm., 1·8 gm. and 2·08 gm. In May *P. sophore* of average sizes of 69·96 mm., 68·8 mm. and 74·1 mm. in total length, corresponding to average weights of 5·0 gm., 5·31 gm. and 6·27 gm., showed a tolerance limit of 5·0%, 11·75% and 0·07% respectively to kier, dye and bleach liquors. *M. vittatus* of average size 75·8 with average corresponding weight of 4·91 gm. showed a tolerance limit of 0·11% with bleach liquor.

The details of range of size and weight of the test animals used in different liquors during experiments are also given in Tables II and III.

The relative comparison of toxicity of various tannery and textile wastes between the two species *P. sophore* and *M. vittatus* observed during the summer month of May show that *M. vittatus* is a considerably hardier fish than *P. sophore* as it can withstand more concentration of factory wastes.

Test of significance applied to differences in survival rates in different months, *i.e.*, December and May, calculated from the basis of observed

data for *P. sophore*, show that except for vegetable tan liquor and dye liquor none of the wastes are significant at 5% level.

Discussion

All industrial wastes are chemically very complex and it is very difficult to define which particular factor is actually responsible for fish kills where they actually occur (Henderson and Tarzwell, 1957; First Progress Report of Aquatic Life Water Quality Criteria, 1955). In such complex wastes any toxicants present may entirely differ from the pure components used for the original chemical action. In the present instance, chromium in tannery wastes is mainly toxic to fish life but due to an excess of lime also used in the process, it is almost completely precipitated as hydroxide in the catch-pits and thus shows practically no ill-effect on fish life in the final liquor.

Klein (1957) states: "Sodium hydroxide and other strong alkalies probably produce asphyxiation by coagulation of gill secretions." Ellis (1937) observed sodium hydroxide to kill carps, shiners and suckers in 96 ppm. of tap-water in 2–10 mts. only. Daugherty (1951) observed fish and crabs to die by the same chemical in 4·5 hrs. and in 5 hrs. when the diluent used was stagnant water. The minimum concentration of 25 ppm. however was recorded by Blending (1927) when the brook trout survived for 24 hrs.

The carbonate alkalinity is also equally toxic. A concentration between 250 and 500 has been observed to be quite toxic. Ellis (*op. cit.*) observed that the above species died in a few hours in concentrations between 250 and 500 ppm. of sodium carbonate and Keller *et al.* (1941), between 7 and 9 hrs. with bass and 4·5–11 hrs. with some other fish in a concentration of 500 ppm.

Similarly the toxic effect of lime is in no way less important. Keller *et al.* (*op. cit.*) observed gold fish, bass and sunfish to survive for 3–5 hrs., gold fish and bass 30–80 minutes in a concentration of 200 ppm. and 20–53 minutes in 500 ppm. respectively; whereas Ellis (*op. cit.*) observed trout to survive only for 26 mts. in 100 ppm.

The above chemicals of which the former two are largely used in textile and tanning industries indicate an average range of their toxicity. The chemical analysis of all the six individual liquors except for the vegetable tan liquor show a high concentration of hydroxide and carbonate alkalinity and possibly affect the fish in high pH by interfering with the mucus coating of the gill membranes bringing about asphyxiation.

The presence of huge amounts of organic substances, especially in the vegetable tan liquor from a tannery, dye and kier liquor from the textile industry, is another important factor to be considered because of their high organic demand (Table I). This is evident from the high 3 minutes permanganate value varying between 295–1460 ppm. Further it was noticed during the course of dilution that the dissolved oxygen to an extent of 8–10 ppm. was quickly reduced to nil. Higher temperature resisted the liquors from attaining higher oxygen saturation which never exceeded 6 ppm. during May. Apart from this factor, a formation of appreciable amount of foam, while oxygenating the liquor, as was observed in the case of vegetable tan liquor, might stand in the way of its attaining a higher saturation value (Gurnham, 1955). While diffusing oxygen directly in vegetable tan liquor a gelatinous-like precipitate was also observed to form and settle, with the light brown colour of the water becoming more intense and turning deep blackish brown, rendering the liquor almost completely opaque. This is exactly what appears to happen when more dilution takes place in the oxygenated river-water.

Hydrogen sulphide at low pH, is highly toxic and ammoniacal nitrogen at high pH, proved injurious to aquatic life. This is because of its presence in molecular form (Doudoroff and Katz, 1950; Henderson and Tarzwell, *op. cit.*) and according to Ellis (*op. cit.*), any concentration up to 2·5 ppm. of ammonia is harmful in the pH range of 7·4–8·5. During experiments the diluted liquors maintained a fairly high pH of 8·0–8·3 except in dye liquor where it was still higher being always above 9·6.

Bleach liquor by itself is quite toxic due to presence of chlorine. This is the only liquor which in minute dilution proved fatal to fish. Toxic effect probably increases with temperature (Allen and Brooks, 1949; Merkens, 1958).

Blending (*op. cit.*) reported toxic range of calcium hypochlorite to be between 0·5 and 10·00 ppm. in the case of trout and other fishes. Doudoroff and Katz (*op. cit.*) mention that various concentrations of chlorine are harmful to fish at different temperatures and from a review of available literature on the subject, indicated that even less than 0·5 ppm. chlorine is harmful to carp and other fishes. Concentration of free chlorine (0·22 ppm.) as observed now was also noted to be toxic by Banerjea *et al.* (1956) and caused a heavy fish mortality in the river Sone (Bihar). They state "though the low D.O. has never been found to be lethal to fish, it is quite possible that it may have had a synergetic effect on the free chlorine so as to make it lethal at that low concentration, which resulted in heavy mortality of fish".

Allen *et al.* (1946, 1948) stated chlorination of certain non-toxic sewage effluents, below their points of chlorine demand, made them highly toxic to fish. Schaut (1939) also gave a similar view while treating dilute KCNS solution with chlorine. The free chlorine value during the present experiments which is also sufficiently low (2·55% in December and 0·07% and 0·11% in May) might as well have had a toxic effect both because of increased temperature of 9–11° C. for December and May and by combining with the organic body secretions, whose presence could have contributed towards a gradual lowering value of chlorine noted during experiments.

The diluted liquors were not analysed in detail like the crude liquors except for pH and dissolved oxygen at various instances during experiments and it was presumed that the entire constituent was proportionately diluted.

Summary

From a study of the results of the foregoing bio-assay with tannery and textile wastes, it can now be safely assumed that the three kinds of tannery wastes studied are harmless to fish life provided at least a dilution of 7–16 times and above are reached in the river stream. Similarly of the three textile wastes (which are let off seldom all at one time), kier liquor is harmless above 19–25 times dilution and dye liquor is less harmful than kier liquor. But bleach liquor, since it contains chlorine, is very toxic and even minute quantities (0·07) may prove harmful to fish under high temperatures.

The high concentration of carbonate alkalinity of all the liquors except vegetable tan liquor, and hydroxide alkalinity of dye and bleach liquors, appears to be highly toxic. Such alkalinity is perhaps as much responsible as the high organic load found in all liquors (except the bleach liquor) because of the presence of huge amounts of putrescible suspended organic matter and organic dyes respecti ely, used in leather tannery and textile mills.

Conclusions

The conclusions now reached are for conditions prevailing at Kanpur, and refer to liquors having characteristics as shown in Table I. The liquors when let into the general sewage system of the city become highly diluted and lose their individual harmful effects first in the city's sewage and later in the great volume of river-water (separate communication by the authors). But when such tannery and textile mills discharge their effluents into quite smaller river streams and ponds or reservoirs, ill-effects, as noted, are bound to be felt requiring individual attention, and the present standards may be applied with advantage, with certain modifications.

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STUDIES ON THE INDIAN SARDINE OIL

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Sardines along with other Clupeids comprise nearly 20% of the total catch which is roughly one million tons per annum. Among the sardines the oil sardines (*Sardinella longiceps*) form the most important group along the West Coast and the fishery spreads over October–March. During the heavy seasons the bulk of the catch is utilized for the manufacture of fish oil and fish guano. The correct assessment of the oil production is not possible as it is manufactured by the private merchants all along the coast. A rough estimate is possible from the oil sardine landings. The approximate percentage of the extractable oil from fresh sardines is 5%. The general method which has undergone very little improvement since its inception which dates back as far as forty years (1921) consists in boiling the fish with water in large iron pans over open fire and pressing the boiled mass in coir bags with the aid of vertical screw presses. The liquid is drained into settling tanks which are interconnected at top and bottom for the separation of oil and water. The separated oil is stored in tins or tanks until it is finally exported. The oil so prepared is mostly used for painting boats and for tempering steel. The versatile uses of the fish-body oils and their products have not assumed much importance in India, due to its uncertain quality and the non-availability of the good oil.

Much work was done on the liver-oils by Kini (1945), Kini and Jayaraman (1947), Sarangadhar (1947) for their Vitamin A content and other chemical characteristics as these are medicinally important. In this paper the author has studied the chemical quality of the commercial sardine oil samples. Good quality sardine oil prepared at Malpe has been used for comparison.

The commercial sardine oil samples collected at various places were manufactured in the traditional method described earlier with very little variations. Along with the commercial samples, sardine oil was prepared in Malpe by boiling the thoroughly washed fish in sufficient quantity of water to avoid scorching of the fish. The oil was pressed from the material through

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thick canvas bags. The oil was allowed to settle and the clean oil was centrifuged and destearinated. The good quality oil so obtained was yellow in colour as compared with commercial oil samples, which were dark brown to black. The chemical constituents were determined for the good quality oil and the commercial samples by the AOAC methods. All the samples were stored in air-tight glass bottles at laboratory temperature (28–32° C.) and the changes during the storage period were observed.

The analysis for the various chemical constituents like the specific gravity, refractive index, acid value, peroxide value, saponification value, unsaponifiable matter and Iodine value for the commercial oil samples are given in Table I. The changes in the acid value, peroxide value, free fatty acids and Iodine value during the storage of the good oil obtained in Malpe are given in Table II *a*. Table II *b* represents the storage quality of the commercial oil samples.

From Table I it is seen that the colour varied from yellow to black in the commercial oil samples. The acid value, free fatty acids and the peroxide values are comparatively higher in the commercial samples than the good quality oil. The dark colour of the commercial samples was due to the scorching of the fish during boiling and prolonged storage with the nitrogenous matter at the bottom of the tanks. The low saponification and high acid value in the Pudiangadi sample shows the hydrolysis of glycerides. The acid values are generally increased during the storage period but the increase was little in the good quality oil when compared with commercial samples (Table II *a* and II *b*). The oils were having an objectionable odour which is due to the degradation products of proteins which are presumably present in the samples. The peroxide value has shown very little increase during its one year storage period in the good quality oil. The results in Table II *a* show that the good quality oil can be preserved for one year without much deterioration. The commercial samples spoil quickly due to the suspended protein material which deteriorates during the storage period. The peroxide formation was delayed in the body-oil samples as compared with liver-oil samples from *Dasyatis and Acetomylaeus maculatus* (Kamasastri, 1959). This may be due to the possible presence of enzyme systems in the body oils or of inhibiting substances present in the fish. This problem needs further investigation. The diversity in the range of chemical constants in the commercial oil and the fluctuations in the sardine fishery (raw material) prevents its use in the leather industry (Nayudamma, 1956), even though the good quality sardine oil possesses the characteristics required for the leather industry. At present imported oils and oil products are used in the leather industry. Besides its uses in the leather industry fish-body

TABLE I

Analysis of commercial sardine oil samples collected during the 1957 season

Sl. No.	Place of collection	Duration of storage (months)	Type of preparation	Colour of the oil	Specific gravity	Refractive index	Acid value	Free fatty acids as % oleic	Iodine value	Peroxide value	Saponification value	Water-soluble fatty acids %	Water-insoluble acids %	Unsaponifiable matter %	Moisture %
1	Kozhikode I ..	4	Kept in sun and oil extracted	Dark-brown	0·933	1·475	13·23	6·66	114·2	4·1	196·5	1·09	87·50	1·06	0·31
2	II ..	4	Fish boiled and oil extracted	,,	0·941	1·476	18·01	9·28	107·60	1·4	213·2	1·30	85·60	1·03	0·79
3	Pudiangadi I ..	2	,,	Black	0·920	1·470	90·63	45·63	99·40	6·3	140·5	1·42	85·94	1·50	..
4	,, II ..	1	,,	,,	0·922	1·471	99·26	49·98	134·20	6·7	157·8	1·34	77·76	1·56	..
5	Pudiappa I ..	4	,,	,,	0·926	1·474	40·27	20·27	126·80	1·39	203·1	2·12	89·33	0·84	0·53
6	,, II ..	1	,,	,,	0·921	1·473	85·07	42·84	149·05	3·07	205·5	2·00	86·34	1·00	0·50
7	Mangalore I ..	Fresh	,,	Dark-brown	0·928	1·475	20·29	10·52	150·7	2·00	207·0	2·23	87·16	1·47	0·92
8	,, II ..	6, 7	,,	,,	0·918	1·471	71·64	35·91	147·2	1·8	203·0	3·43	90·05	1·47	..
9	Malpe ..	1	,,	Brown	0·925	1·475	11·52	5·8	161·0	Nil	195·6	0·09	94·12	0·58	0·15
10	Malpe (good oil extracted)	Fresh	,,	Yellow	0·925	1·475	11·50	5·79	161·0	Nil	195·6	0·09	94·12	0·58	0·15

TABLE II *a*

Storage studies on the good quality sardine oil obtained from Malpe

(Storage period)

Chemical constants	Fresh	45 days	120 days	180 days	210 days	285 days	345 days
Acid value ..	11·50	11·40	11·5	11·98	12·43	12·96	19·72
Free fatty acids ..	5·79	5·74	5·80	6·03	6·26	6·53	9·88
Iodine value ..	161·0	160·00	156·2	150·0	154·6	138·0	135·9
Peroxide value ..	Nil	Nil	Nil	Nil	Nil	Nil	0·38

TABLE II *b*

Analysis of seven months' old sample (commercial)

Chemical constants	Pudiappa 210 days	Pudiangadi I 245 days	Pudiangadi II 210 days
Acid value ..	118·5	98·63	103·2
Free fatty acids ..	59·65	49·66	51·74
Iodine value ..	149	145·7	134
Peroxide value ..	2·1	1·05	1·3

oils, find versatile uses in textile, cosmetics and various food industries. In an organised exploitation of the sardine fishery, application of modern wet reduction processes and strict quality control are necessary for the production of good quality sardine oil.

SUMMARY

The commercial sardine oil samples were analysed and the deterioration in the quality during storage was studied along with the sardine oil prepared in controlled conditions. The good quality oil can be preserved for one year without much deterioration.

ACKNOWLEDGEMENT

I acknowledge with thanks the co-operation rendered by the officers-in-charge at Calicut and Mangalore in procuring the oil samples. I also thank Shri C. V. G. Reddi for finding the refractive indices of the oil samples. I am indebted to Dr. S. Jones for his keen interest in this investigation.

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A COMPARATIVE STUDY OF CERTAIN CHARACTERISTICS OF THE COMMON VEGETABLE FIBRE TWINES FOR FISHING NETS*

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Introduction

Twisted twines are essential components for fabrication of fishing nets and other similar snares. Selection of twines for the different gear depends on the one hand upon the dynamic characteristics and on the other, the extent of availability of the raw materials. The degree of twist and the uniformity in the distribution of the material, as denoted by the diameter and the mass per unit length, are important traits in selecting suitable twines. The softness of twist is of particular significance in gill-nets. Strength and elongation or stretch are other indispensable qualities of twines contributing in large measure to the catch efficiency and life of the concerned gear. Resistance to abrasion is yet another important characteristic particularly for those used for trawl nets and other towed gear, where rubbing and resultant friction are general features than the exception. Evaluation of the above indicated inherent properties, their concomitance and inter-relationship are basic essentialities in the programme for improvement of the existing fishing nets in vogue and introduction of their relatively modern counterparts.

Although man made fibre (synthetic) twines are becoming increasingly popular in other countries, from the economic standpoint and other related considerations, the mainstay of fishing nets in India will continue to be fibres of vegetable origin, at least till such time cheap synthetic equivalents are produced within the country. The majority of the vegetable fibres are procured from indigenous sources; a few varieties are, however, imported. The present paper deals with the initial study conducted by the authors for a comparative evaluation of certain characteristics of the common vegetable fishing net twines. The work was undertaken at the suggestion of Dr. H. Miyamoto, F.A.O. Gear Technologist. To him the authors' grateful thanks are due, for the painstaking guidance during the course of experiments and the criticism offered for the preparation of this paper.

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* Contribution No. 19.

Materials and Method

In the present study, which as indicated earlier is only an initial attempt, seven varieties of common vegetable fibre twines were subjected to the preliminary tests. Table I presents the list of materials; the known trade specifications are noted against each.

Table I

Showing the specification of materials

Serial No.	Material (Common name)	Trade specifications
(i)	Madras sann hemp	Number 31, 10 ply
(ii)	Italian hemp	2×4 ply
(iii)	Flax	Not known
(iv)	Indian sisal	2 mm. (in diameter)
(v)	Manila	2 mm. (in diameter)
(vi)	Indian cotton	Count No. 20, 3 ply, 63 threads
(vii)	Malabar coir	Superior Angengo

Italian hemp, flax and Manila are imported into the country. Apart from flax all the other materials are extensively used in the Indian fishing industry. In choosing the different materials the diameter of the twines was taken as the approximate standard base of equity.

The diameter in millimetres, the mass per metre length in grams, the dry and wet (48 hours immersion) breaking strength in kilograms and the percentage stretch both in dry and wet conditions were recorded. The results are based on 100 tests and subsequent statistical analysis of the data. The mean (arithmetric mean) and the standard deviation were calculated employing the conventional formulæ (Waugh, 1952) for grouped data and they are:

Arithmetic mean

$$X = X' + Ci \frac{\Sigma(fd)}{N},$$

TABLE II

The analysed data of the tests conducted

Sl. No.	Name of material	Diameter in mm.				Mass in gm./metre					Breaking strength in kgm.				Percentage breaking stretch			
		U.L.	L.L.	'X'	σ	U.L.	L.L.	'X'	σ		U.L.	L.L.	'X'	σ	U.L.	L.L.	'X'	σ
(i)	Sann hemp	2·90	1·91	2·26	0·228	3·86	2·44	3·31	0·300	D	44·5	26·5	32·75	3·510	7·66	4·00	5·81	0·910
										W	50·5	28·0	37·15	3·722	13·66	9·33	11·60	1·024
(ii)	Italian hemp	2·38	1·89	2·08	0·095	3·79	2·92	3·39	0·175	D	77·5	51·5	67·50	4·845	9·00	6·60	7·97	0·515
										W	80·0	53·0	69·45	5·405	18·20	11·6	16·02	1·274
(iii)	Flax	2·48	2·05	2·21	0·110	3·88	2·52	2·93	0·263	D	60·0	31·5	44·60	5·595	10·66	6·66	8·78	0·952
										W	62·5	36·5	50·95	5·625	19·33	14·00	16·66	1·126
(iv)	Sisal	2·66	2·04	2·38	0·111	4·30	2·60	3·28	0·329	D	53·0	25·0	36·05	5·375	12·33	7·00	9·57	0·995
										W	53·0	25·0	38·95	5·740	18·00	11·00	14·55	1·351
(v)	Manila	2·99	2·20	2·66	0·167	4·56	3·02	3·90	0·380	D	65·0	34·0	50·25	6·400	11·33	7·33	9·09	0·910
										W	74·5	37·5	53·70	5·675	18·00	13·00	15·89	1·246
(vi)	Cotton	2·40	2·07	2·21	0·069	2·48	2·16	2·34	0·071	D	31·5	21·5	27·02	1·732	25·23	15·66	21·1	1·702
										W	35·0	25·0	30·74	2·184	29·33	24·00	26·74	0·982
(vii)	Coir	3·17	2·02	2·57	0·238	3·03	1·31	2·04	0·362	D	13·5	4·0	9·06	1·979	28·33	12·33	21·20	3·68
										W	12·5	4·0	8·38	2·062	35·33	13·33	25·95	4·21

U.L. = Upper limit; L.L. = Lower limit; 'X' = Arithmetic mean; σ = Standard deviation; D = Dry and W = Wet.

where X' is the assumed mean, Ci the class interval, $\Sigma(fd)$ the sum of the deviations and N the number of observations, and
Standard deviation

$$\sigma = Ci \sqrt{\frac{\Sigma(fd)^2}{N} - \left(\frac{\Sigma(fd)}{N}\right)^2},$$

where Ci is the class interval; $\Sigma(fd)^2$ the summation of the squares of deviation; $\Sigma(fd)$ the summation of deviation and N the number of observations.

Results

The results of the observations (arithmetic mean) are tabulated in Table II.

(*a*) *Diameter.*—Figure 1 shows the range of variation of the diameter of the different twines compared. It will be observed that while cotton and Italian hemp are fairly uniform in thickness, Madras sann hemp and coir twines appear considerably coarse.

(*b*) *Mass.*—Figure 2 shows the range of variation in the mass per unit length. Italian hemp and cotton twines studied have fairly uniform mass as evidenced by the Text-Figure, and sann hemp and coir fall far below the above standards, having apparently no uniformity in the distribution of the fibres in the twines.

(*c*) *Breaking strength.*—Figure 3 depicts the dry and wet breaking strength of twines. The deviation in the strength appears to be high in all the twines studied.

(*d*) *Breaking stretch.*—Figure 4 shows the variations in dry and wet breaking stretch (percentage to the tested length) of the twines. In all the materials compared cotton and coir exhibit relatively high properties of stretch.

Discussion

(*a*) *Diameter and mass.*—Diameter of the twines is an important characteristic to determine the effect of currents on a given piece of webbing, the pull on the net by the moving fish and the power required or speed attained in the case of a towed gear (Carrothers, 1957). Similarly the mass of twine is another important factor to be reckoned while designing a net (Reuter, 1957). Apart from economic considerations of cost and amount of material used, the mass of twine also helps to determine the total weight of the gear which in turn is indicative of the buoyancy and gravitational forces necessary to keep the net in the concerned fishing position.

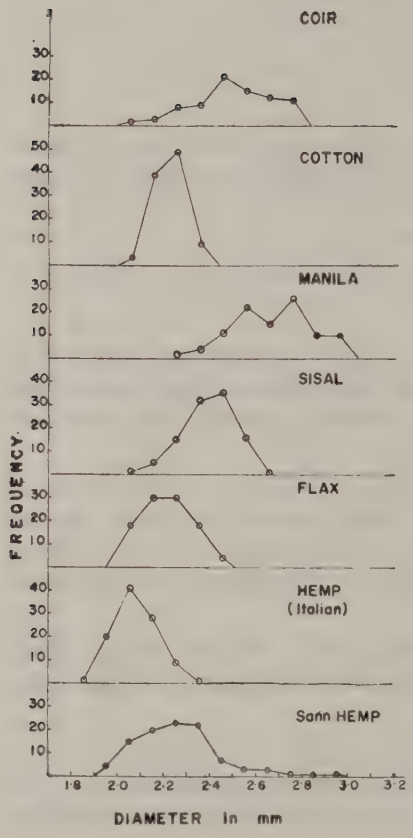

FIG. 1

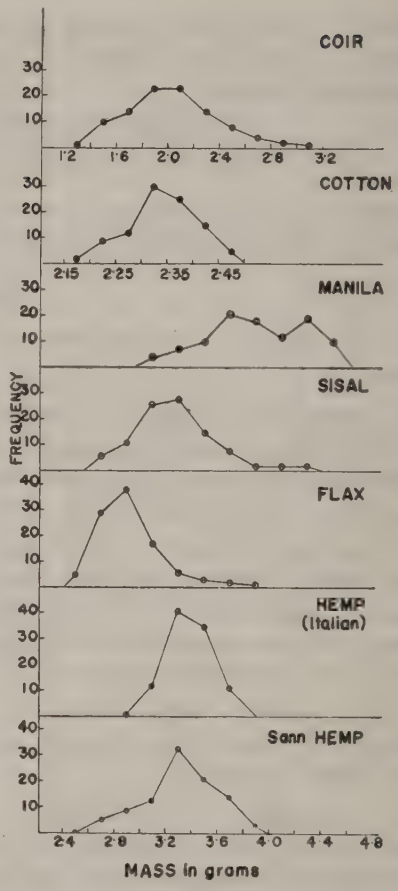

FIG. 2

FIGS. 1-2. Fig. 1. Frequency polygon showing the range of variation of the diameter of the twines. Fig. 2. Frequency polygon showing the range of variation in the mass per unit length of the twines.

Both these essential characteristics severally and conjointly denote the uniformity in the thickness and the distribution of the material in the twines. Netting twines should be uniform in thickness. It will be observed from Table I that cotton twine is most even in thickness; that the Italian hemp is the most evenly twisted among hemp twines and that the Madras sann-hemp twine exhibit rather high percentage of deviation both in its diameter and mass per unit length. The non-uniformity in the thickness of these sann hemp twines is suggestive of some defect in the procedure or process

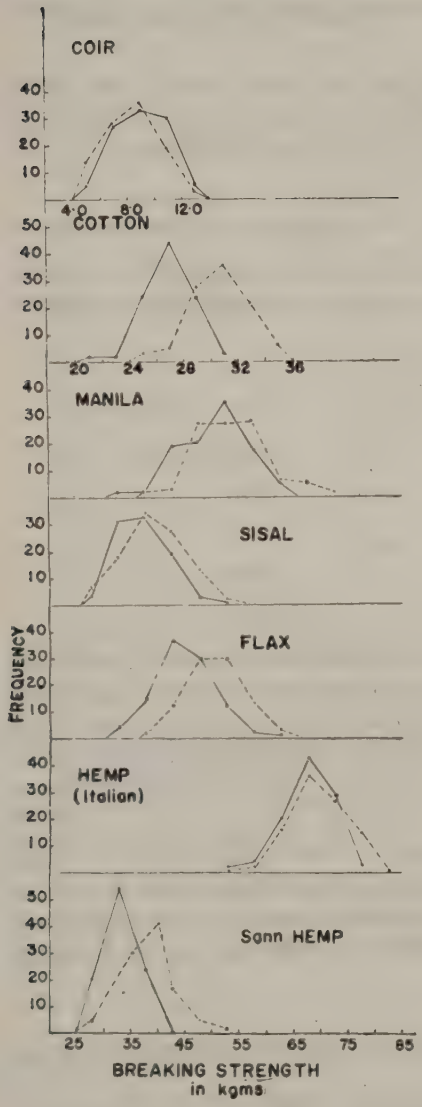

FIG. 3

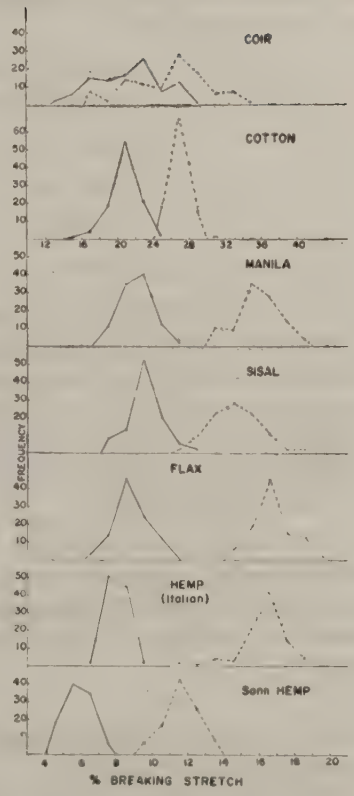

FIG. 4

FIGS. 3–4. Fig. 3. Frequency polygon showing the range of variation of dry and wet breaking strength of twines. Fig. 4. Frequency polygon showing the range of variation of dry and wet breaking stretch of twines.

of its manufacture. Miyamoto and Shariff (1959) in their studies have also indicated the poor quality of Madras sann hemp twines used for fishing nets.

In an earlier communication (Kuriyan and Cecily, 1959) it has already been propounded that mass per unit length of the twine is directly proportional to the square of the diameter of the twine. Therefore,

$$W = KD^2,$$

where W is the mass per unit length, D, the diameter and K the constant.

When W represents mass in grams per metre length of twine and D, the diameter in mm., the constant K in this relationship for the different twines compared are:

	(i) Madras sann hemp	.. 0·65
	(ii) Italian hemp ..	.. 0·78
	(iii) Flax	.. 0·60
	(iv) Sisal	.. 0·58
	(v) Manila	.. 0·56
	(vi) Cotton	.. 0·48
and	(vii) Coir	.. 0·31

As the above indicated values of K show mass of twine in grams per mm.^{2} of D^2, they would serve as an index to denote the relative mass of the concerned material. In the present instance Italian hemp is more heavy than the other materials of the same thickness with sann hemp, flax, sisal, manila, cotton and coir following in that order. Coir is the lightest among the materials compared.

(*b*) *Strength.*—As indicated elsewhere in this communication strength is an essential characteristic governing the catch efficiency and the life of the concerned gear. Breaking strength is proportional to the mass per unit length of the twines. This relationship is represented in the following formula

$$S = KW,$$

where S is the breaking strength, W, the mass per unit length and K, the constant in this relationship.

The values of K for the dry and wet twines of the materials under comparison is tabulated in Table III. Since S is in kgm. and W in grams per metre length of twine, the values of K denote the breaking strength in kgm. per one gram metre of twine.

TABLE III

The values of the constant K *in the strength-mass relationship*

Sl. No.	Material	Value of K		Percentage increase in strength of wet twines
		In dry	In wet	
(i)	Sann hemp	9·92	11·26	13·5
(ii)	Italian hemp	20·25	20·61	1·8
(iii)	Flax	15·19	17·35	14·2
(iv)	Sisal	11·00	11·90	8·2
(v)	Manila	12·88	13·77	6·9
(vi)	Cotton	11·50	13·20	14·8
(vii)	Coir	4·45	4·12	— 7·5

The constant K would serve as reference figure indicating the relative strength of twines of the same mass. In the present comparative study, Italian hemp is observed to be nearly twice stronger than Madras sann hemp.

The percentage increase in breaking strength is shown in the last column of Table III. Except in the case of coir, the strength of all the twines increase in the wet condition. Coir lose their breaking strength when wet and this fact corroborates the view of Gopalan Nayar (1959).

That the strength of twines is proportional to the square of the diameter has already been indicated elsewhere (Kuriyan and Cecily, *op. cit.*). The formula depicting the above relationship is

$$S = KD^2,$$

where S denotes the strength; D the diameter and K the constant.

Founded on the above hypothesis of strength-thickness relationship, the calculated constant K for materials compared is tabulated in Table IV. Here S is in kgm., D in mm. and the values of K would therefore be breaking strength in kgm. per one mm.^{2} of D^2.

TABLE IV

The values of the constant K *in the strength-thickness relationship*

Sl. No.	Material	Values of *K*		Percentage increase in strength of wet twines
		In dry	In wet	
(i)	Sann hemp	6·4	7·42	16·1
(ii)	Italian hemp	15·64	16·10	2·9
(iii)	Flax	9·13	10·43	14·2
(iv)	Sisal	6·35	6·86	8·1
(v)	Manila	7·16	7·65	6·9
(vi)	Cotton	5·55	6·30	13·5
(vii)	Coir	1·21	1·12	— 7·5

Cotton and sann hemp are the main net webbing materials produced in India. Fairly large quantities of Italian hemp twines are being imported for 'Dara' gill-nets in Bombay State primarily due to extra strength of these twines. When compared with the Italian hemp of the same mass, the Madras sann hemp studied appear to be only half as strong. It must be admitted that the sample of sann hemp analysed was of poor quality being badly twisted, and non-uniform in thickness. These characteristics, if improved, could apparently increase the strength property of the twine. Similar studies on the sann hemp twines produced in other Indian States also appear necessary prior to attempting to suggest an alternative indigenous twine to replace the imported Italian hemp twine.

Coir and Sisal are indigenous fibres used for making ropes essential for fishing nets. Coir appear to be weak. On the contrary Sisal is almost as strong as Manila, a view already established earlier (Anon 1933).

(*c*) *Breaking stretch.*—The breaking stretch of materials is of particular importance in fishing net fabrication. The relation between strain and stretch is the factor by which the resilience of the twine can be represented.

In all the materials studied the stretch when wet appears to be more than when dry. Table II shows the stretch property of each twine and in

general cotton and coir twines possess large percentage of stretch when compared with hemps and flax.

Summary

Certain characteristics of the common vegetable fibre twines used for fabrication of fishing nets are presented. The interrelationships of these characteristics are indicated.

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ON THE COMPARATIVE CATCH EFFICIENCY OF HAND-OPERATED AND WINCH-OPERATED TRAWLS*

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I. Introduction

That the motorization of the indigenous fishing crafts and the introduction of modern designs of mechanized fishing boats provide the background impetus for an improvement of the existing fishing gear and methods is too well known. Some of the maritime States in India have completed the first phase of the general 'mechanization' programme, namely—the installation of engines for propulsion in the existing fishing boats (Setna, 1955; Deshpande, 1958; Gurtner, 1958; Kuriyan and Balasubramanyan, 1959). The next step obviously is the introduction of modern fishing gear to increase the catch-per-unit effort and thereby to be in commensurate with the extra capital outlay. Chidambaram (1952) and John *et al.* (1959) review the attempts made earlier for the introduction of new gear in Indian waters.

"Trawls" are effective modern gear provided they are operated by skilled personnel. Although extensive work have been done elsewhere on the design, construction and operation of the different types of trawls, very little information is available on record about the comparative catch efficiency of hand-operated and winch-operated trawls with which the present communication deals.

II. Place of Experiment, Fishing Grounds and Period of Operation

Experimental trawl fishing is being conducted both on the East and West Coast of India from fully and partly mechanized vessels. In the sea off Cochin, where the present study was made, otter trawl for shrimps is the most popular gear operated from the different motor fishing boats.

Two motorized fishing vessels 'Tarpon' and 'Sagarkumari' attached to the Government of India Off-shore Fishing Station, Cochin, were selected for carrying out the present study. Observations of fishing operation under-

* Contribution No. 23.

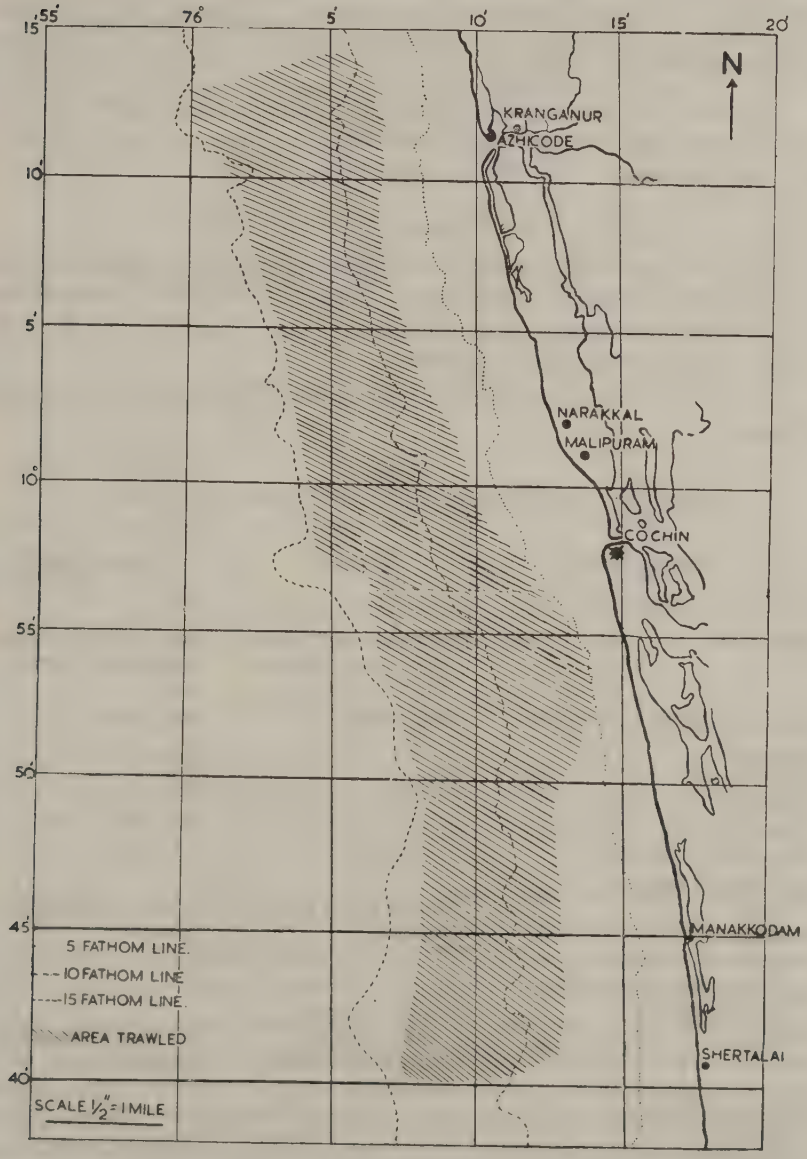

FIG. 1. Chart showing fishing grounds off Cochin.

taken by these vessels commenced from 1–12–1958 and continued up to 31–3–1959. During the period of four months, 71 fishing trips were made by each vessel. The fishing grounds were within 9° 40′–10° 14′ N. latitude and 76° 0′–76° 14′ E. longitude.

Particulars regarding the size of the net, fishing grounds, depth of water, length of warp used for each drag, duration of the drag, and catch per haul, etc., were recorded.

III. Particulars of Fishing Vessels

Both the vessels are identical in design and power of engine provided and other essential details. The vessel ' Tarpon ' is, however, equipped with a power-driven mechanical winch whereas the vessel ' Sagarkumari ' is devoid of any mechanical fishing equipment.

The specifications of the vessels along with the other details are tabulated in Table I.

Table I

Showing the specifications and other details of the vessels

Specification	'Tarpon'	'Sagarkumari'
Design ..	Medium-sized fishing vessel with transom stern	Medium-sized fishing vessel with transom stern
Year and place of construction ..	1955, Japan	1955, Japan
Dimensions:		
Length ..	34′– 4″	34′– 4″
Breadth ..	11′– 0″	11′– 0″
Depth ..	4′–11″	4′–11″
Registered tonnage ..	8·45 tons	8·45 tons
Particulars of Engine:		
Type ..	Marine diesel engine	Marine diesel engine
Make ..	Yanmar	Yanmar
B.H.P. ..	42	42
Particulars of winch and warp:		
Type of winch ..	With wire drums	..
Warp ..	9 mm. diameter galvanised flexible steel wire	19·05 mm. diameter manila rope
Particulars of crew:		
Bosun ..	1	1
Mechanic ..	1	1
Lascars ..	3	4

IV. Particulars of Fishing Gear

The mechanized fishing vessels 'Tarpon' and 'Sagarkumari' used four-seaming, non-overhang otter trawl nets, the particulars of which are shown in Table II. The nets had legs, spreaders, bridles and sweeps.

Table II

Showing particulars of the nets

Name of vessel	Type of net used	Mesh size (stretched)	Size of O.B.		Length of		Distance between *O.B.* and wings
			Dim.	*Wt.*	*H.R.*	*F.R.*	
Tarpon ..	Four-seaming Non-overhang trawl	Cod-end —1″ Rest —2″	58″× 26·5″	110 lb.	51′	51·5′	37′
Sagarkumari	Do.	Do.	42″×25″	58·5 lb.	40′	40·5′	43·5′

Note: *H.R.*—Head rope; *F R.*—Foot rope; *Dim.*—Dimensions; *O.B.*—Otter Board; *Wt.*—Weight.

V. Method of Operation

(i) *Deck arrangement.*—Since the vessel 'Sagarkumari' was without winch, certain arrangements were made to facilitate towing of the warp. Two iron chains 4–5′ (121–152·4 cm.) in length were fixed together to the rear of the fishhold towards stern-deck.

Manila ropes 0·75″ (19·05 mm.) diameter and one fathom in length were tied to the free ends of the chains. Two iron hooks were attached to these ropes by splicing their ends. To facilitate securing of warps on-board, each towline was spliced at a distance of 55 and 70 fathoms.

(ii) *Shooting.*—The shooting of the nets in both these vessels were carried out following the conventional way. After taking necessary soundings (for depth of water and nature of sea-bottom) of the fishing grounds on each day, the net was paid out in the order of cod-end, legs, bridles, sweeps, otter-boards and warp. Time required for shooting the warp in respect of each vessel was recorded and shown in Table III. The towing speed ranged between 2–2·5 knots per hour. It would be observed from Table

III that the time required for shooting the warp is more or less the same for both the vessels.

(iii) *Duration of drag.*—3–4 regular fishing hauls were made by these vessels on each day. The duration of each drag was between 60 and 90 minutes.

(iv) *Hauling.*—The hauling in of net in case of 'Tarpon' was effected by winch. The heaving operations were carried out by hand onboard 'Sagarkumari' after placing the engine in neutral position. The time required for heaving the warps recorded in respect of each vessel is shown in the last column in Table III.

TABLE III

Showing the time required for shooting and hauling in the warps

Name of vessel	Depth in fathoms	Length of warp used in fathoms	Time required in minutes for	
			Shooting	Hauling
Tarpon ..	5 –15	50–70	3·5–5	5–6
Sagarkumari ..	3·5–13	55–70	4–5	7–16

It would be obvious from Table III that the hand-operated trawl required more time for heaving the warps.

VI. RESULTS

The quantity of fish landed by these vessels along with the other details are tabulated in Table IV.

TABLE IV

Showing particulars of catch landed by these vessels

Name of vessel	Fishing trips	Fishing hauls	Duration of hauls		Catch			Catch per hour		
			Hrs.	Mts.	Prawn (lb.)	Fish (lb).	Total (lb.)	Prawn (lb.)	Fish (lb.)	Total (lb.)
Tarpon ..	71	335	330	33	29,805	60,844	90,649	90	184	274
Sagarkumari ..	71	347	369	47	25,384	26,209	51,593	69	71	140

The catch data reveal that the catch per hour of trawling is more in the case of mechanically operated trawl net. The catch per hour on the grounds operated works out to 90 lb. of prawns and 184 lb. of fishes in case of 'Tarpon' and 69 lb. of prawns and 71 lb. of fishes in case of 'Sagarkumari'.

VII. Discussions

1. *Catch-per-unit volume of water filtered*

The quantity of fish caught by a trawl net has a direct bearing on the volume of water filtered by it during a certain period and the volume of water filtered by a net in turn depends on the vertical and horizontal mouth-opening of the net while in action. The volume of water filtered per hour by the nets operated was worked out by taking into consideration the opening of the net while being towed in water.

Opening of the net in action.—One of the major factors influencing the catch of a trawl is the vertical and horizontal area of the ground fished by the net. Takayama and Koyama (1959) and Okonski and Sadowski (1959) suggest that the vertical opening of the mouth of the trawl is important and depends mainly on the length of the ' headrope ' and ' footrope '. Phillips (1959) states that the vertical plane is more essential than the horizontal for high swimming fish and " the height of the headline has a more direct bearing on the potential catching power than the spread caused by the trawl doors". Ben-yami (1959) describes the method of calculating the opening height and width of a trawl net and also suggests " pattern considered to be cheap, strong and efficient trawl net for the Mediterranean Sea where an increase in the fishing height may be of far greater importance ". de Boer (1959) gives an account of the interesting results obtained by his underwater instruments, such as spread-meter and net-height meter, for recording the behaviour of trawl gear. Chikamosa Hamuro and Kenji Ishi (1959) used an automatic net-height meter to ascertain the height of the headline and wings of a trawl net in action. Scarfe (1959) recommends echo-sounding as a means of observing the performance of trawling gear and further states that the height of the opening, the position of danlenos and otter boards in regard to the net opening can be observed from echo-gram. The vertical and horizontal opening of the nets operated by ' Tarpon ' and ' Sagarkumari ' were worked out and the procedure followed in calculating the opening height and width of each net along with the other details are described under the appropriate paras.

(*a*) *Vertical opening of the net.*—The grounds where fishing was carried out by 'Tarpon ' and ' Sagarkumari ' were inhabited by prawns which adhere

to the sea-bottom during daytime and as such the vertical fishing height of the net was not of much importance. For want of modern equipments, the vertical elevation of net was estimated from the length of the headrope or size of the net.* The vertical height assessed in respect of nets operated by 'Tarpon' and 'Sagarkumari' are given below:

Vessel		Length of headrope	Estimated vertical height
Tarpon	..	51′	4·5′
Sagarkumari	..	40′	3·6′

(*b*) *Horizontal opening of the net.*—The horizontal opening of the net in action was considered to be of great importance. The probable opening of each net, while being towed in water, was worked out from the actual measurements taken during the course of fishing. The method employed in calculating the approximate distance between the otter-boards was based on measuring the distance between the warps at two particular points on board the vessel during each day. This method, although not correct, suffices to procure the probable distance between two doors. The following equation was used in calculating the horizontal opening between otter-boards:

$$L : B = l : b.$$

Therefore,

$$B = \frac{b \times L}{l}$$

where

L denotes the length of warp used while trawling,

B the horizontal distance between two doors,

l the marked length of warp from the point A where both the warps are secured together onboard, and

b the horizontal distance between the ends of l.

Here L in operation is known and if we can measure l on both the warps correctly, then b can be easily measured as illustrated in Fig. 3.

* Based on a personal communication from Dr. H. Miyamoto.

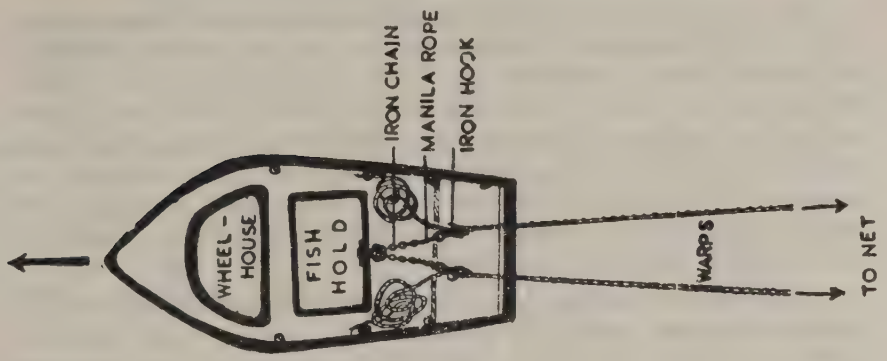

FIG. 2

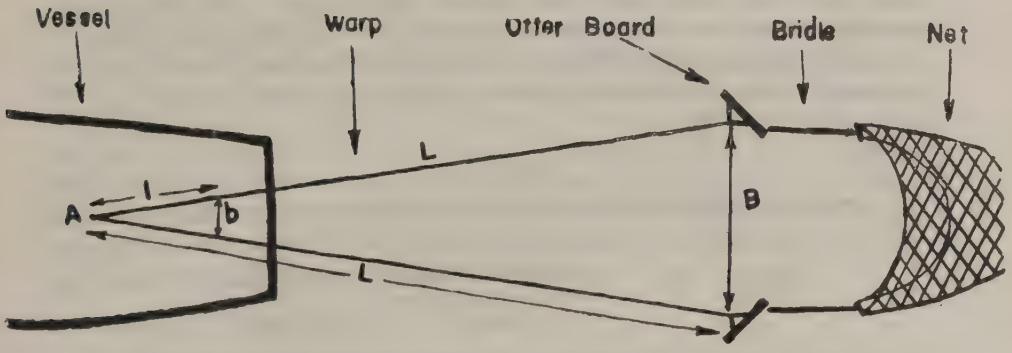

FIG. 3

FIGS. 2–3. Fig. 2. Showing deck arrangement on board 'Sagarkumari'. Fig. 3. Showing procedure followed in measuring the horizontal spread.

The results obtained after calculating the horizontal distance between two doors reveals as follows:

Vessel	Approximate distance between two doors
Tarpon ..	58·14′
Sagarkumari ..	37·89′

The horizontal opening thus procured is not the actual mouth-opening of the net while fishing but the distance between two otter-boards. However, this distance helps in calculating the actual opening of the net or distance between the two wings. Presuming that the headrope with legs, bridles and sweeps maintains a catenary curve while being pulled along the sea-bottom and since the distance between the doors and wings is known, the horizontal distance between the two wings can be easily measured. The following procedure was followed in measuring the horizontal opening of the net under laboratory conditions.

Two nails were fixed on the wall at a distance already obtained (the distance between two doors). An iron chain (thin) having length equivalent to the total length of headrope, legs, bridles and sweeps (of either side) was hung, by its free ends on to these nails. The chain thus hung maintains a catenary curve. The distance between door and wing was marked on either side of this chain from its free ends or from the nails. The horizontal distance between these two marks was measured indicating the expected horizontal mouth-opening of the net or the distance between the two wings. Particulars of the above measurements obtained in respect of each vessel are tabulated in Table V.

TABLE V

Showing horizontal distance between doors and wings of each net

Vessel	Horizontal distance in feet between	
	Doors	Wings
Tarpon ..	58	38
Sagarkumari ..	38	24

After ascertaining the horizontal and vertical opening of the net and average towing speed of the vessel per hour while trawling, the volume of water filtered per hour by each net was calculated from the following formula:

$$V = B \times H \times S,$$

where

V denotes the volume of water filtered,

B and H the horizontal and vertical openings respectively, and

S the distance for which the net was towed during one hour.

The volume of water filtered by the nets operated by 'Tarpon' and 'Sagarkumari' are recorded in Table VI.

TABLE VI

Showing the volume of water filtered by each net and the catch per unit volume of water filtered

Vessel	Average trawling speed	Vertical fishing height	Horizontal fishing height	Volume of water filtered per hour (c.ft.)	Catch-per-unit volume (1,00,000 c.ft.)	
					Prawns	Fish
Tarpon ..	2·0	4·5′	38′	20,52,000	44	99
Sagarkumari	2·5	3·6′	24′	12,96,000	63	55

Presuming 1,00,000 c.ft. of filtered water as a unit for both these nets, the quantity of prawns and fish caught by filtering 10^5 c.ft. of water by the vessel 'Tarpon' and 'Sagarkumari' comes to 44 lb., 90 lb. and 53 lb. and 55 lb. respectively (Table VI). Therefore, the quantity of fish caught per unit of filtered water is more in case of winch-operated trawl whereas the quantity of prawns is more or less the same in case of both the nets. The difference in catch so far as fish and prawns are concerned indicates that *bigger net increases the vertical fishing height of a net whereas the smaller net catches more from the horizontal plane (nearer to the bottom).*

2. *Catch per unit area covered*

The catch of fish and prawns caught per unit area covered by the nets operated by these vessels and tabulated in Table VII was worked out by taking into consideration the towing speed and horizontal opening of the net in action.

TABLE VII

Showing catch in lb. per 100 sq.ft. of area of the sea floor

Vessel	Catch in lb. per hour		Towing speed in knots per hour	Horizontal opening in ft.	Total area covered per hour in sq.ft.	Catch in lb. per 100 sq.ft.	
	Prawn	Fish				Prawn	Fish
Tarpon ..	29,805	60,844	2·0	38	4,56,000	6·53	13·34
Sagarkumari	25,384	26,209	2·5	24	3,60,000	7·05	7·28

It would be evident from Table VII that there is not much difference in the quantity of prawns landed by each vessel. *The catch data further reveals that the prawns were distributed evenly along the sea bed and as such the vertical opening or fishing height of the net is not important while trawling for shrimps.*

Comparing the catch of fish landed by each vessel, it is clear that the catch per 100 sq.ft. of area scooped by the nets operated by ' Tarpon ' and ' Sagarkumari ' comes to 13·34 lb. and 7·28 lb. respectively. *The difference between the fish catch further indicates that the fishes dwell not only along the sea-floor but also swim above it and as such the vertical fishing height of the net is of greater importance while trawling for fishes.*

3. *Relation between hauling time and catch*

Time required for heaving the warps during each haul and the quantity of fish caught by the net during each drag were recorded and mentioned under appropriate paras earlier. The quantity of fish caught per haul and time required for hauling-in the warps is illustrated in Fig. 5.

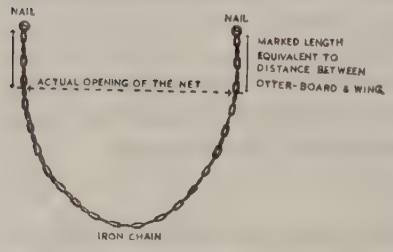

FIG. 4

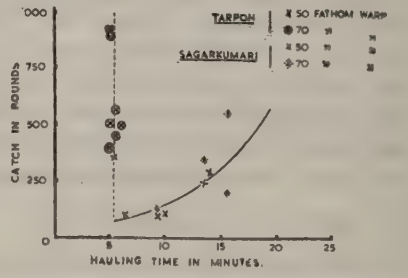

FIG. 5

FIGS. 4–5. Fig. 4 Showing arrangements made for calculating the actual opening of a trawl net. Fig. 5. Showing the relation between the quantity of fish caught and the time required for taking the warps onboard in respect of 'Tarpon' and 'Sagarkumari'.

The above graph indicates that the time required for heaving the warps by hand depends entirely on the quantity of fish enmeshed in the codend region (provided there is not much difference in the length of warp used while trawling), whereas it remains constant throughout in case of trawls operated by mechanical means.

VIII. Recapitulation of Advantages of Mechanically Operated Trawl Net

Based on the results of observations made during the course of studies, the following have been noted to be the decided advantages of the mechanically operated modern gear:

(i) The number of crew engaged while fishing is less in case of nets operated by winch.

(ii) The hand-operated vessel could not operate a bigger net than the one operated by her as more hands are necessary for hauling-in a bigger net.

(iii) Though the time required for shooting the net is same in case of 'Tarpon' and 'Sagarkumari', the hauling-in of warps by hand required more time. Moreover, the vessel 'Sagarkumari' had to be stopped from going ahead while heaving the net which resulted in escape of some of the fishes from the net.

(iv) The number and duration of hauls were more in case of 'Sagarkumari' as prolonged trawling results in additional labour and time for taking the increased catches onboard.

(v) While comparing the opening of the nets, it can be deduced that the opening is more in case of fully mechanized craft. One of the factors responsible for getting less spread in the net operated by 'Sagarkumari' is the size of the warp (0·75″ Manila rope) which offers more water resistance while being towed.

(vi) Comparing the catch efficiency per unit effort, it can be concluded that the catch is more in case of 'Tarpon'. The catch per hour comes to 274 lb. and 140 lb. in respect of winch and hand-operated trawl net.

Both the methods of operation are being practised in India and the present author is however of the opinion that, if trawling is to be conducted commercially, powered operations would increase efficiency.

IX. Acknowledgements

The author wishes to express gratitude to Dr. H. Miyamoto, F.A.O. Gear Technologist assigned to this Station, for his guidance and suggesting the problem. The author is also indebted to Shri G. K. Kuriyan, Assistant Director (Gear), Central Fisheries Technological Research Station, Cochin, for going through the manuscript and making useful suggestions. The author wishes to record his sincere thanks to Shri A. T. Shariff, Assistant Director, Off-shore Fishing Station, Cochin, for the valuable field data made available during the course of investigations. To the Bosuns of the mechanised vessels 'Tarpon' and 'Sagarkumari' the author is thankful for affording facilities to take necessary measurements during fishing voyages onboard the respective vessels.

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THE COMMON CHARACTERISTICS OF COTTON FISHING NET TWINES—EXPERIMENT SERIES II*

By G. K. Kuriyan and (Miss) P. J. Cecily

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The essentials to the economic well being of a developing national industry are the availability and the production of the basic raw materials within the concerned country. The Indian fishing industry, as the mainstay to ensure progress in exploitation, depends on fibres of vegetable origin. The majority of these fibres, cotton (*Gossipium* spp.) being the most important among them, are procured from indigenous sources. Notwithstanding the increasing demand from the Textile and other allied industries, a fair percentage of the country's annual production of cotton fibres, twisted in the form of threads, twines and ropes, is consumed by the fishing industry for fabrication of nets and other gear. Regardless of the importance as a net material, it must be admitted that very little information is available on record evaluating the dynamic characteristics of cotton twines. In an earlier communication (Kuriyan and Cecily, 1959) the authors presented an account of the preliminary studies conducted by them for the evaluation of the common characteristics of cotton fishing net twines. The present paper describes the Second Experiment Series in these investigations and embodies the results of analysis of a separate set of Indian machine-twisted twines. While the first set were 'Soft' twisted, the present series comprise of samples with 'Hard' twist.

The authors are particularly indebted to Dr. H. Miyamoto, F.A.O. Gear Technologist, on assignment with the Station, for suggesting and guiding the investigation.

Materials and Method

Machine twisted cotton twines of the following specifications and manufactured by a twine twisting factory in Bombay were taken up for the present study:

Count No. 20 (Tex. No. 29·5); 3 strands (ply) 9, 12, 15, 18, 21, 24, 27, 30, 36, 42, 48, 54 and 60 threads (yarns).

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* Contribution No. 20.

Mass of twine, diameter, outer and inner twists, breaking strength and stretch both in dry and wet (48 hours-immersion) conditions were recorded. Similar to the earlier experimental series, the effect of the trawl and reef knots on the strength of twines was also observed.

Mass, diameter and breaking strength and stretch of twines were determined on the basis of 100 tests, while the other characteristics were ascertained based on 30 tests. The conventional formulæ for grouped and ungrouped data were employed for calculation of the standard deviation (σ) and they are:

(*a*) For 100 tests (grouped data):

$$\sigma = Ci \sqrt{\frac{\Sigma (fd)^2}{N} - \left(\frac{\Sigma fd}{N}\right)^2},$$

where Ci is the class interval; d the class deviation; f the frequency and N the number of observations.

(*b*) For 30 tests (un-grouped data):

$$\sigma = \sqrt{\frac{\Sigma (x)^2}{N}}$$

where $\Sigma (x)^2$ is the summation of the squares of the deviation of each observation from the mean and N the number of observations.

Results

The results are tabulated in Tables I to V. Mass is expressed in grams per metre length of twine, diameter in millimetres, breaking strength in kilograms and breaking stretch in percentage of the tested length.

Discussion

(i) *Mass and diameter.*—It would be evident from Table I that the twines analysed are fairly uniform in regard to mass per unit length and diameter.

The relationship between mass and the number of threads in the twine and mass and the square of the diameter of the twine are indicated in Figs. 1 and 2. Mass is proportional to the number of threads and also to the square of the diameter of the twine. The formulæ propounded in the earlier communication (Kuriyan and Cecily, *op. cit.*) to depict these

TABLE I

The analysed data about mass and diameter of the twines

No. of threads	Mass in gm.				Diameter in millimetres			
	Upper limit	Lower limit	X	σ	Upper limit	Lower limit	X	σ
9	0·40	0·32	0·36	0·024	0·83	0·63	0·72	0·042
12	0·51	0·44	0·47	0·020	0·97	0·75	0·87	0·040
15 ..	0·68	0·58	0·63	0·020	1·04	0·88	0·95	0·040
18 ..	0·80	0·70	0·76	0·022	1·12	0·97	1·04	0·040
21 ..	0·95	0·82	0·87	0·030	1·20	1·02	1·09	0·050
24 ..	1·04	0·94	0·98	0·021	1·24	1·09	1·15	0·033
27 ..	1·19	1·08	1·22	0·023	1·34	1·18	1·25	0·040
30 ..	1·29	1·22	1·25	0·020	1·34	1·22	1·28	0·031
36 ..	1·46	1·34	1·39	0·027	1·45	1·31	1·39	0·030
42 ..	1·94	1·74	1·86	0·041	1·59	1·44	1·54	0·030
48 ..	2·24	2·01	2·12	0·058	1·78	1·58	1·67	0·050
54 ..	2·41	2·30	2·37	0·027	1·85	1·73	1·78	0·040
60 ..	2·80	2·61	2·67	0·043	1·96	1·83	1·88	0·031

X = Arithmetic mean; σ = Standard deviation.

TABLE II

The analysed data about outer and inner twists of the twines

No. of threads	Outer twist per inch				Inner twist per inch			
	Upper limit	Lower limit	X	σ	Upper limit	Lower limit	X	σ
9	11·6	10·1	10·84	0·29	42·80	38·30	41·00	0·83
12	11·2	9·1	10·05	0·37	39·60	31·30	34·68	1·18
15	9·6	7·4	8·20	0·55	36·40	29·80	32·51	1·24
18	8·3	7·6	7·92	0·15	31·10	27·70	29·65	0·89
21	8·2	7·4	7·60	0·37	28·00	21·00	25·06	1·56
24	8·4	7·4	7·90	0·30	26·20	22·20	24·40	0·88
27	7·2	6·0	6·50	0·32	25·40	17·60	21·50	2·02
30	7·2	6·0	6·60	0·25	23·40	20·00	22·20	1·10
36	6·0	5·0	5·40	0·24	18·50	15·40	16·80	0·77
42	5·6	5·2	5·50	0·28	15·40	12·80	14·10	0·64
48	6·0	5·2	5·50	0·20	16·90	14·00	15·45	0·97
54	5·6	5·1	5·40	0·13	17·20	13·40	15·26	0·79
60	5·4	4·8	5·00	0·16	17·20	15·20	16·03	0·35

X = Arithmetic mean; σ = Standard deviation.

TABLE III

The dry and wet breaking strength of twines

No. of threads	Dry breaking strength in kgm.				Wet breaking strength in kgm.			
	Upper limit	Lower limit	X	σ	Upper limit	Lower limit	X	σ
9	4·90	3·20	4·19	0·33	5·5	3·9	4·83	0·36
12	6·00	4·20	5·18	0·36	7·3	4·9	6·34	0·45
15	7·20	4·70	6·13	0·48	8·7	5·7	7·29	0·64
18	10·60	7·20	8·69	0·62	12·7	6·9	9·69	0·98
21	12·00	8·80	10·46	0·60	12·9	9·3	11·56	0·66
24	11·70	10·40	11·20	0·34	13·0	10·2	11·60	0·66
27	14·60	10·40	12·54	0·75	15·3	11·3	13·20	0·90
30	15·30	13·50	14·10	0·47	16·0	13·4	14·90	0·65
36	18·20	14·40	16·62	0·94	19·6	15·0	17·20	0·84
42	20·80	15·30	17·74	1·06	20·8	15·0	18·68	1·18
48	23·00	16·00	20·84	1·36	25·0	20·0	22·78	1·10
54	25·80	20·60	23·70	1·25	26·6	22·6	24·55	1·08
60	30·80	21·20	25·90	2·40	29·4	25·4	27·39	1·19

X = Arithmetic mean; σ = Standard deviation.

TABLE IV

The percentage breaking stretch of dry and wet twines

No. of threads	Dry breaking stretch in %				Wet breaking stretch in %			
	Upper limit	Lower limit	X	σ	Upper limit	Lower limit	X	σ
9	18·89	11·41	14·52	1·45	34·50	22·20	27·16	3·00
12	22·20	13·90	17·22	1·89	37·80	28·60	33·78	2·24
15	28·40	16·60	24·22	2·49	35·00	26·70	30·68	2·01
18	26·70	17·20	21·94	1·89	35·60	24·40	30·03	2·85
21	22·80	15·60	18·84	1·62	35·60	27·00	30·32	2·24
24	30·60	17·20	21·94	3·20	33·80	27·00	29·80	1·62
27	37·20	15·80	25·74	4·81	40·00	30·30	34·50	2·65
30	25·00	19·40	21·80	1·02	34·50	27·80	30·80	1·77
36	25·00	17·50	21·62	1·62	36·20	27·80	32·50	1·82
42	32·80	20·00	26·64	2·86	43·00	33·40	37·24	1·70
48	30·00	23·40	26·70	1·30	42·50	31·70	36·50	2·18
54	27·80	22·20	26·01	1·42	36·60	28·90	32·40	1·78
60	28·80	23·40	26·40	1·85	38·30	30·60	35·22	2·19

X = Arithmetic mean; σ = Standard deviation.

TABLE V

The breaking strength of twines with knot

No. of threads	Breaking strength in kgm. of twines with knot*							
	Trawl knot				Reef knot			
	Dry		Wet		Dry		Wet	
	Top mesh	Side mesh	Top mesh	Side mesh	Top mesh	Side mesh	Top mesh	Side mesh
9	3·30	3·30	3·55	3·68	3·50	2·98	4·10	3·28
12	4·07	4·60	4·80	5·30	4·55	4·00	5·35	4·30
15	4·75	5·35	5·32	6·65	5·49	4·51	5·98	5·08
18	6·75	6·83	7·05	7·55	6·95	6·15	7·35	6·40
21	7·10	7·55	8·05	8·35	7·65	6·70	9·15	6·85
24	7·60	8·44	9·10	10·00	9·88	7·45	9·50	8·52
27	8·92	10·37	10·10	11·33	10·60	9·30	11·30	9·70
30	10·28	10·67	10·70	11·80	10·42	9·35	11·83	10·86
36	11·60	11·78	12·05	13·00	11·75	10·35	13·35	11·75
42	13·05	14·10	15·35	15·53	14·20	12·71	16·20	14·70
48	13·81	14·51	16·26	17·38	15·47	12·95	16·82	15·92
54	14·46	15·93	16·76	17·45	15·59	15·41	20·05	17·38
60	17·32	18·81	18·35	19·10	19·66	18·31	22·60	18·20

* The figures represent the calculated arithmetic mean of 30 tests.

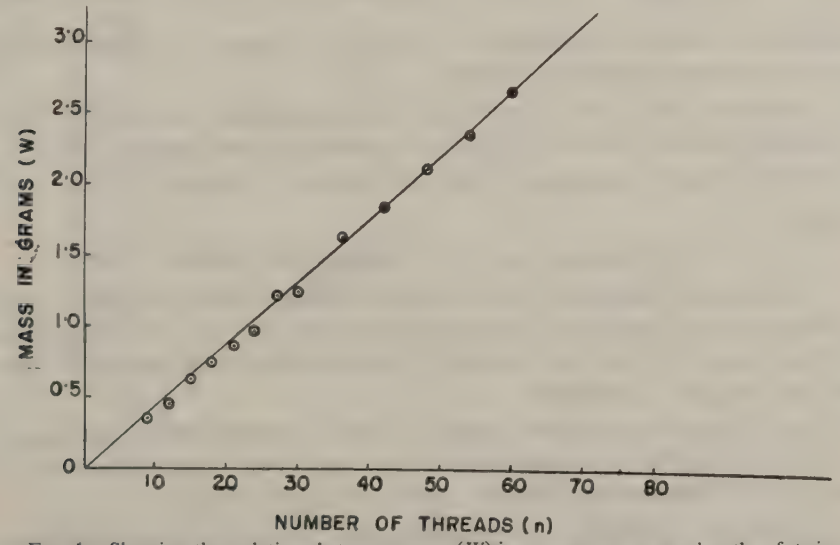

FIG. 1. Showing the relation between mass (W) in grams per metre length of twine and the number of threads (n).

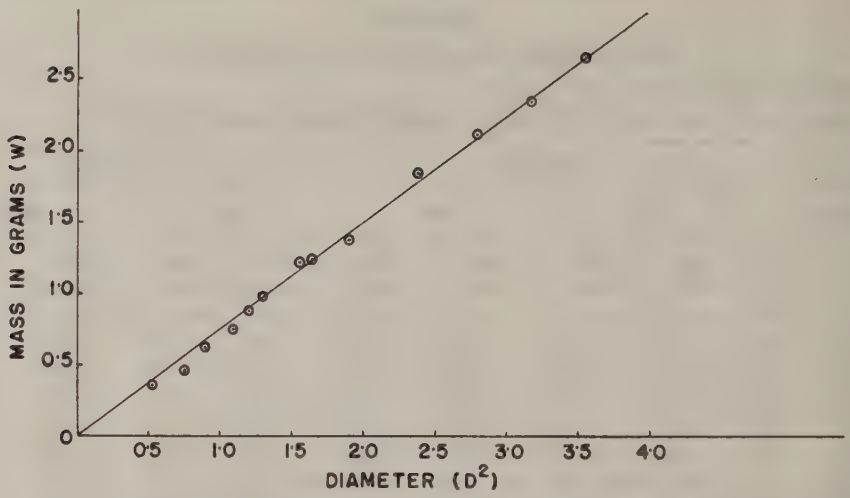

FIG. 2. Showing the relation between mass (W) in grams per metre length and the square of the diameter (D) of the twine.

relationships are:

$$W = Kn$$

and

$$W = KD^2,$$

where W is mass per unit length, n, number of threads, D, diameter and K, the constant in each relationship.

Figures 1 and 2 also support the above indicated relationships. The constants K when worked out by the 'method of least squares' are:

$K = 0{\cdot}044$ (in the mass g./m. and number of threads)

and

$K = 0{\cdot}75$ (in the mass g./m. and square of the diameter in mm.).

The similar constants for soft twisted twines analysed earlier were 0·036 and 0·55 respectively (Kuriyan and Cecily, *op. cit.*). The differences in the values of K are attributable to the difference in the degree of twist in the two sets of samples.

(*ii*) *Twists.*—As indicated earlier in this communication, the twines used for the present experimental series were hard twisted. Figure 3 depicts the relationship between inner and outer twists.

The chief difficulty in twisting twines is to give the appropriate outer twist in relation to the inner twist of the strands. Since the outer

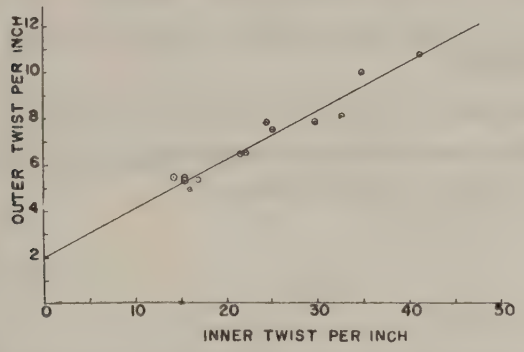

FIG. 3. Showing the relation between inner and outer twists of twines.

twist is invariaoly opposite in direction to the inner twist, a twine which is not given the correct outer twist will always be unstable and is susceptible to twist in the direction of the outer or inner twist, which is more than the optimum. The samples studied in the earlier experimental series were extremely badly twisted from this standpoint, while the present series appear to comprise comparatively of evenly twisted twines as would be evident from Fig. 3.

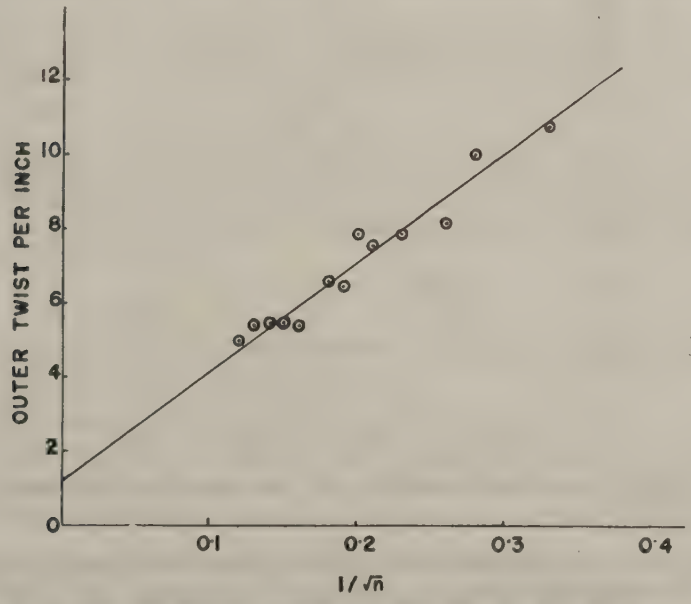

FIG. 4. Showing the relation between outer twist and $1/\sqrt{n}$. (n = number of thread in the twine.)

Based on Fig. 3 the relation between outer and inner twist can be represented as follows:

No. of outer twist = 0·213 × No. of inner twist + 12.

As the authors already indicated elsewhere (Kuriyan and Cecily, *op. cit.*), if the degree of twist is constant, then,

$$T: T_1 = \sqrt{n_1}: \sqrt{n}$$

and

$$T: T_1 = D_1: D$$

where, T and T_1 represent the number of twist per unit length and n and n_1 the number of threads in the twines and D and D_1 the respective diameters.

The number of twist is, therefore, inversely proportional to the square-root of the number of threads and the diameter of the twine.

Figures 4 and 5 show the relation between the outer and inner twists and the square root of the number of threads ($1/\sqrt{n}$). The Figures also substantiate the above hypothesis.

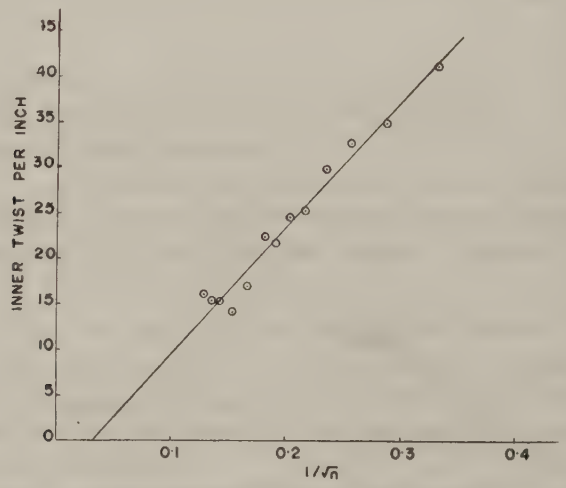

FIG. 5. Showing the relation between the inner twist and $1/\sqrt{n}$. (n = number of threads in the twine.)

From Fig. 4 the relation between the outer twist and the square root of the number of threads ($1/\sqrt{n}$) can be worked out as:

$$To = (29{\cdot}75 \times 1/\sqrt{n}) + 1{\cdot}2.$$

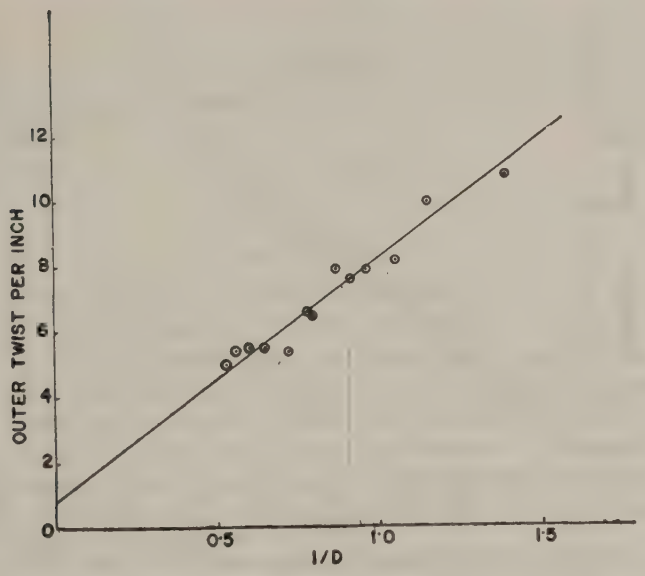

FIG. 6. Showing the relation between outer twists and diameter of the twines ($1/D$).

From Fig. 6 the relation between inner twist and the square root of the number of threads ($1/\sqrt{n}$) of each strand can be worked out as follows:

$$Ti = 137 \times 1/\sqrt{n} - 4{\cdot}3.$$

Figure 6 represents the relation between the outer twist and the respective diameters ($1/D$) of the twines. From the Figure the relation between the outer twist (To) per inch of twine and the diameter (D) in mm. can be worked out as:

$$To = (7{\cdot}48 \times 1/D) + 0{\cdot}8.$$

The samples were fairly well twisted taking into consideration the diameter and the number of outer twist.

(*iii*) *Breaking strength.*—Figs. 7 and 8 represent the relationship between the breaking strength (dry and wet) and the number of threads and the square of the diameter of the twines. From the Figures it would be evident that breaking strength is proportional to both these factors.

Let S denote the breaking strength of twines in kgm. and n the number of threads, then, from Fig. 7, S can be expressed as follows:

$$S = 0{\cdot}425n + 0{\cdot}25 \text{ in dry condition}$$

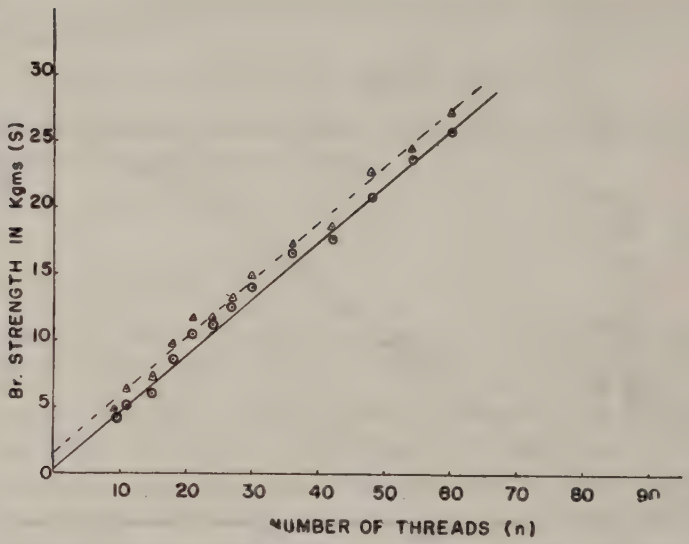

FIG. 7. Showing the relation between breaking strength (S) in kgm. and the number of threads (n).

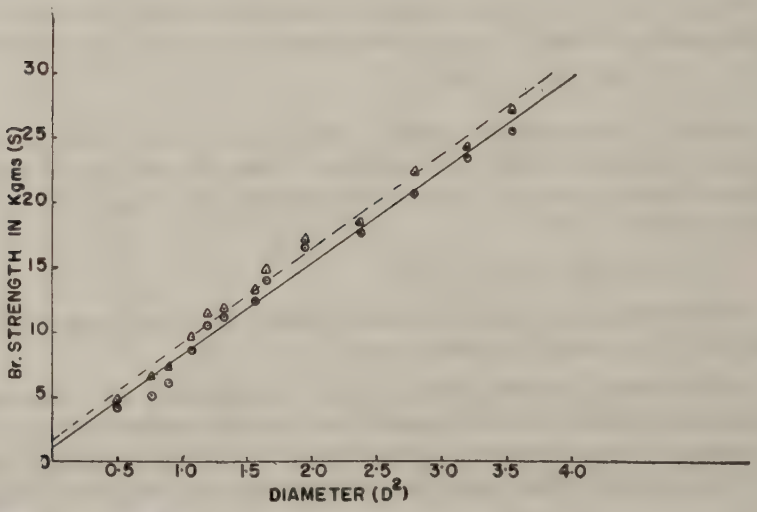

FIG. 8. Showing the relation between breaking strength (S) in kgm. and square of the diameter (D) of twines.

and

$$S = 0{\cdot}43n + 1{\cdot}5 \text{ in wet condition.}$$

Relation between diameter of twine (D) and S is worked out from Fig. 8 as follows:

$$S = 7{\cdot}25D^2 + 1{\cdot}0 \text{ in dry condition}$$

and

$$S = 7{\cdot}5D^2 + 1{\cdot}5 \text{ in wet condition.}$$

In the first series, the values of the constants were $0{\cdot}49n$ (dry), $0{\cdot}55n$ (wet) and $7{\cdot}1\ D^2$ (dry) and $8{\cdot}2\ D^2$ (wet) respectively. Though it may not be quite accurate to compare these two results on account of the possible differences that might exist in the qualities of the cotton fibres constituting the basic threads of the twines in the two series, the samples of the latter series appear to be a little weaker than the former. This may be partly due to the 'hard' twists of the twines of the II series. However, further experiments are necessary to reasonably assess the effect of twists on the breaking strength of twines.

Although in the present series as well the twines record an increase in the breaking strength as a result of wetting (48 hours immersion), the increase in strength is not as much as that of the twines of 20-count thread of I series. This fall in the wet breaking strength is partly attributable to the hard nature of the twists of the twines of the II series.

(*iv*) *Breaking stretch.*—Fig. 9 shows the trend of relation between the percentage breaking stretch and the number of threads.

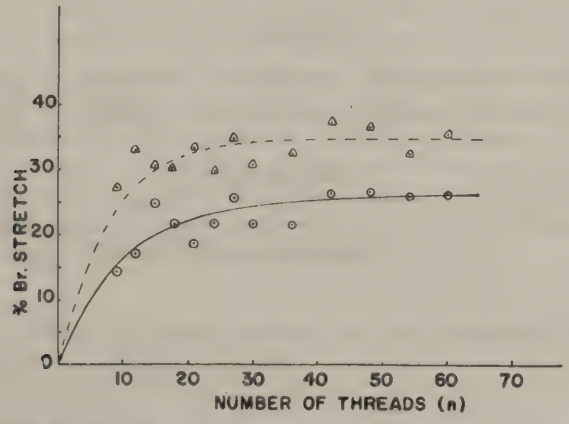

FIG. 9. Showing the percentage breaking stretch and the number of threads.

Although the samples of the II series record only a lower breaking strength, when compared with the samples of the earlier series, the elongation till the breaking point is distinctly more in the second set of twines. It could, therefore, be assumed that harder the twist greater the breaking stretch.

(*v*) *Effects of knots.*—The percentage loss in strength of the twines while made into reef knots and trawl knots is presented in Table VI. From the table it would be evident that while in the trawl knot the loss of strength is greater in the direction of the top mesh, in the reef knot the loss is greater towards the side mesh.

TABLE VI

The percentage decrease in the original breaking strength at knot

	Trawl knot				Reef knot			
	Dry		Wet		Dry		Wet	
	Top mesh	Side mesh	Top mesh	Side mesh	Top mesh	Side mesh	Top mesh	Side mesh
Mean ..	28·45	23·14	26·93	20·93	20·97	31·09	18·83	30·43
Maximum ..	38·99	32·78	33·01	30·27	34·22	37·86	26·16	40·74
Minimum ..	21·24	11·19	18·18	8·78	10·44	22·78	14·33	21·64

SUMMARY

The paper describes the results of a II series of experiments to evaluate the common characteristics of cotton fishing net twines.

REFERENCE

Kuriyan, G. K. and Cecily, P. J. 1959 The common characteristics of cotton fishing net twines—A preliminary account. *Indian Jour. Fish.*, **6** (2), 399–409.

PRELIMINARY STUDIES OF CERTAIN CHARACTERISTICS OF SPHERICAL FISHING FLOATS*

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Introduction

Float or floating material is one of the essential components of a fishing net. The catch capacity of a net is to a large extent governed by a corresponding efficiency of the floats used. The characteristic features that contribute to a relative efficiency of a float are:

1. Extra-buoyancy;
2. Reduction of the buoyant force due to absorption of water;
3. Capacity to withstand the different water pressures at various depths; and
4. Strength against shocks, abrasion and rotting.

The abundance in availability and the cheap price also substantially exercise influence in the selection of a floating material for a fishing net.

Pieces of indigenous light wood are extensively employed for different types of nets in India. In the wake of introduction of modern fishing gear like trawl nets, bottom-set gill nets and purse seines, the need for glass, metallic and synthetic floats is increasingly felt at all the mechanised fishing centres. Although glass, aluminium alloy and synthetic floats are being manufactured in this country, no systematic attempt has so far been made to study the characteristics and fishing utility features of these Indian made floats. The present communication, which is only a preliminary account, is an enumeration of such a study. Comparison of some of the characteristics of floats manufactured in India with those of foreign countries has also been attempted.

Material and Method

Material

Table I indicates the type, material and the commercial specifications of floats included in the present study.

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* Contribution No. 18.

TABLE I

	Material of the float	Country where manufactured	Shape	Commercial specification (diameter)
1.	Glass	India	Hollow sphere	4″, 5″ and 6″
2.	Glass	Norway	,, ,,	3½″, 5″ and 6″
3.	Aluminium alloy	India	,, ,,	5″ and 6¼″
4.	Aluminium alloy	England	,, ,,	7½″ and 8″
5.	Aluminium alloy	Norway	,, ,,	8″
6.	Plastic	Norway	,, ,,	5″
7.	Plastic	Denmark	,, ,,	6″ and 8″
8.	Synthetic rubber	Japan	Not hollow	5″

(*a*) *Glass floats.*—The sample of Indian glass floats studied were manufactured in Bombay and they seem to have been prepared by blowing the melted liquid to the required size. The floats made in India were transparent with light bluish green tint, whereas their Norwegian counterparts were in different colours. In general, large-sized floats were either green or dark green, while the small-sized ones were of greenish blue, green, black and black-tinged. The glass floats are to be attached to the gear by means of thick webbing, fabricated around them, which also incidentally prevents breakage to a large extent.

(*b*) *Metal floats.*—The Indian metal floats were made by 14 gauge Aluminium-Manganese alloy (Trade name "INDAL 3S"). The floats appear to have been made in two halves which are pressed, welded at the seam and on top is provided with a lug having one eye of the dimensions and shape as shown in Fig. 1 *a*, by means of which it is fixed to the head rope of the net. They are coated with black anti-corrosive paint which stops the surface withering, when exposed to water and air while in usage.

The aluminium alloy floats of English and Norwegian make are large in size and these are fitted with a strong two 'eye handle' for attachment to the head rope (Fig. 1 *b*).

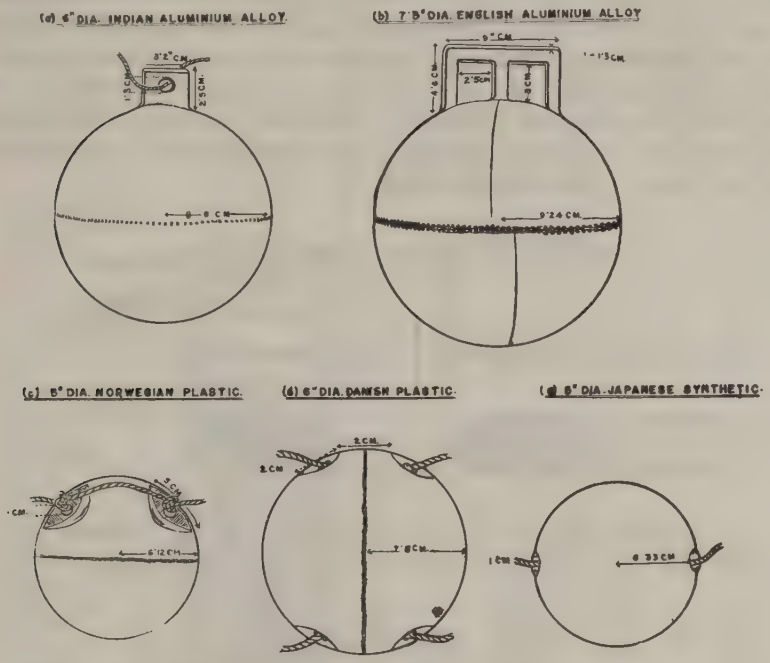

(a) 6" DIA. INDIAN ALUMINIUM ALLOY
(b) 7·5" DIA. ENGLISH ALUMINIUM ALLOY
(c) 5" DIA. NORWEGIAN PLASTIC
(d) 6" DIA. DANISH PLASTIC
(e) 8" DIA. JAPANESE SYNTHETIC

FIG. 1. Showing the floats and the arrangement for fixing them to the gear.

(*c*) *Other floats.*—Mostly these consist of Plastic of three different sizes of 5″, 6″ and 8″ in diameter, among whom the smallest size is made in Norway and coloured white, having two circular depressions on either side of the upper half, with an arc-like projection in the centre containing a perforation for passing rope or string to be attached to the gear (Fig. 1 *c*). The two remaining are manufactured under trade name "NOKALAN" in Denmark and grey in colour. The arrangement provided for its tying to the gear consists of a groove on both sides of dimensions shown in diagram (Fig. 1 *d*). A small sample of Japanese made synthetic rubber of pink hue, with a groove at the centre for attachment to the head rope of the gear is also included (Fig. 1 *e*).

Method

Diameter in centimetre, the weight in air and extra-buoyancy in grams of each sample were recorded.

The equipment used to find out the buoyant force is described below. To a circular iron frame, suitable length of webbing was attached with

sufficient slackness so as to appear like a scoop-net. Three cotton strings of same length were tied at equidistant points on the frame and their free ends were knotted together, and attached to a bunch of lead sinkers of enough weight to keep the float submerged in water completely. Two more cotton twines were fastened to the frame above on diametrically opposite points. The entire apparatus was suspended from a small wooden piece as shown in the diagram (Fig. 2).

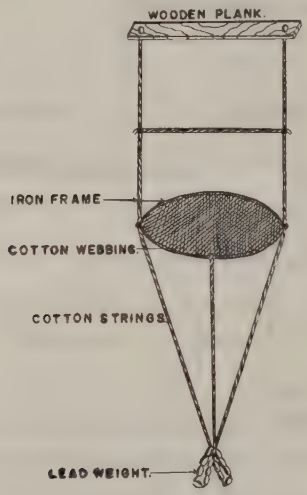


FIG. 2

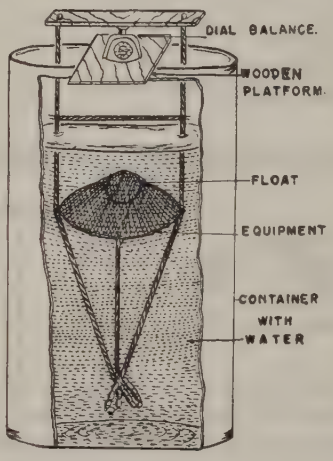


FIG. 3

FIGS. 2–3. Fig. 2. Equipment to keep the float under water used to find out its extra-buoyancy. Fig. 3. Arrangement for measuring the extra-buoyancy of the float.

The arrangement and method adopted to find out the lifting capacity was as follows:

A big container with water almost full was taken and a wooden platform was laid across on top of it. On this plank was placed a dial balance and the above equipment was suspended in the water, keeping the wooden piece on the pan of the balance (Fig. 3). Initially the weight of lead in water was noted. Then the float was inserted into frame under the webbing, taking care to see that the float is completely submerged under water, and the readings on the balance recorded. The difference in these two readings is the extra-buoyant force or the lifting capacity of the float.

RESULTS

The results obtained are presented in Table II.

TABLE II

Showing average or mean diameter, weight and extra-buoyancy of the sample of floats studied together with their standard deviation

No.	Material used and manufacturing country of the float	Commercial specification (diameter) (in inches)	Number of sample studied	Diameter		Weight		Extra-buoyancy		Remarks
				Average in cm.	σ	Average in gm.	σ	Average in gm.	σ	
1	2	3	4	5	6	7	8	9	10	11
1	Glass (India) ..	4	100	10·17	0·054	311·87	46·95	238·28	51·09	} Bluish green in colour
2	,, ..	5	74	12·68	0·036	465·31	39·99	579·30	37·00	
3	,, ..	6	50	15·29	0·033	576·82	45·32	1,263·82	43·37	
4	Glass (Norway) ..	$3\frac{1}{2}$	50	8·65	0·150	143·73	15·83	191·50	20·87	Greenish blue coloured
5	,, ..	$3\frac{1}{2}$	51	8·88	0·042	177·68	15·23	179·12	17·21	Black coloured
6	,, ..	$3\frac{1}{2}$	50	8·81	0·091	151·89	15·06	194·08	19·67	Green coloured
7	,, ..	$3\frac{1}{2}$	13	8·88	0·039	167·37	13·32	181·54	12·11	Black tinged
8	,, ..	5	18	12·68	0·196	396·83	34·81	639·04	35·91	Green and dark-green coloured
9	,, ..	6	25	15·28	0·051	585·42	25·88	1,213·09	35·33	,,
10	Aluminium alloy (India)	5	38	12·74	0·047	257·74	3·46	788·18	8·48	Black anti-corrosive coated
11	,, ..	$6\frac{1}{4}$	50	16·01	0·130	391·22	11·75	1,662·12	13·77	,,
12	Aluminium alloy (England)	$7\frac{1}{2}$	26	18·47	0·070	1,083·83	20·73	2,135·52	25·97	Philips company
13	,, ..	8	4	20·02	·030	1,339·54	27·31	2,282·18	33·19	,,
14	Aluminium alloy (Norway)	8	45	20·42	0·061	1,672·49	14·85	2,673·93	15·33	,,
15	Plastic (Norway) ..	5	25	12·24	0·045	161·87	4·02	735·10	5·22	Milk-white in colour
16	,, (Denmark)	6	50	15·55	0·033	292·28	3·17	1,639·02	5·13	Trade name: NOKALAN Grey in colour
17	,, ..	8	15	19·77	0·100	635·97	4·47	3,292·79	6·97	,,
18	Synthetic rubber (Japan) ..	5	7	12·71	0·090	392·84	17·72	611·54	15·11	Pink in colour

For purposes of comparison, similar data for the spherical glass floats made in Japan (Miyamoto, 1952) are given in Table III.

TABLE III

Showing the diameter, weight and extra-buoyancy of Japanese glass floats

No.	Commercial specification (diameter)	Diameter in cm.	Weight in gm.	Extra-buoyancy in gm.
1	2½″	6·06	56	61
2	3 ″	7·58	94	135
3	3½″	9·10	150	288
4	4 ″	10·60	206	423
5	5 ″	12·10	300	633
6	5½″	13·60	450	880
7	6 ″	15·15	637	1,170
8	7½″	18·30	975	2,210
9	8½″	21·20	1,430	3,650
10	10 ″	24·20	2,100	5,620
11	12 ″	30·30	3,560	10,900

(Courtesy: Dr. H. Miyamoto, 1952.)

The formula adopted for determining the standard deviation is given below:

$$\sigma = \sqrt{\frac{\Sigma (x)^2}{(n-1)}},$$

where x denotes the deviation of each observation from the mean and n, the number of observations.

The frequency distribution diagrams of each sample are shown in Figs. 4 *a*, *b*, *c*.

It is evident from the histograms that the range of variation in weight and extra-buoyancy are too apparent in the case of glass floats rather than in metal or plastic floats.

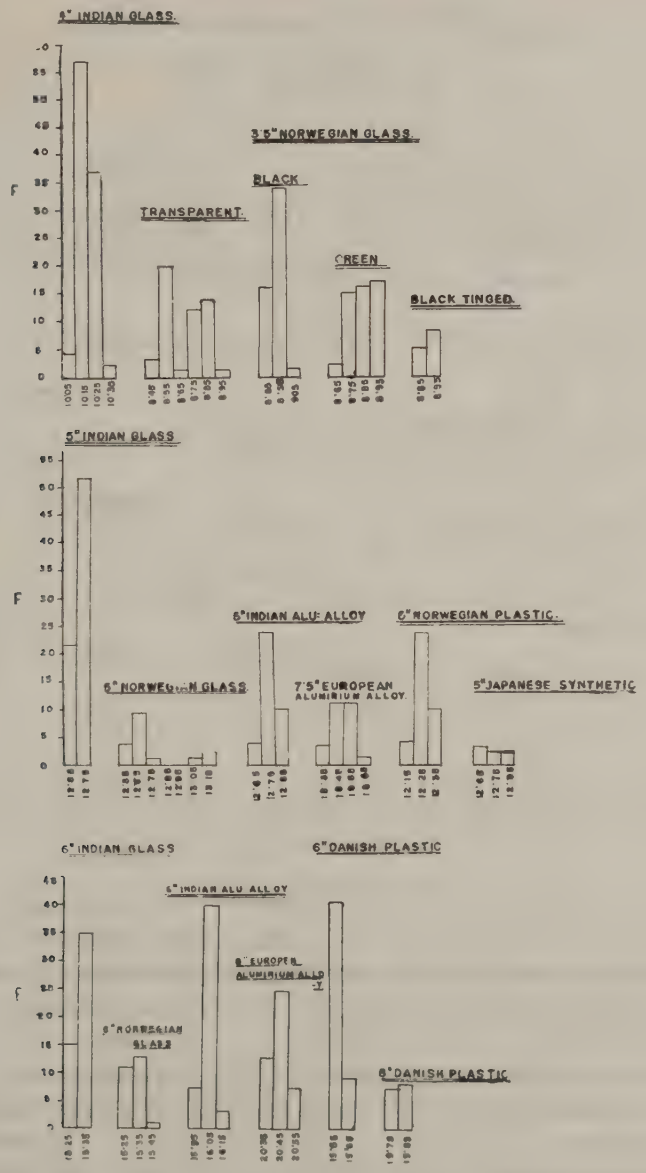


FIG. 4 (*a*). Diameter (Centimetres).

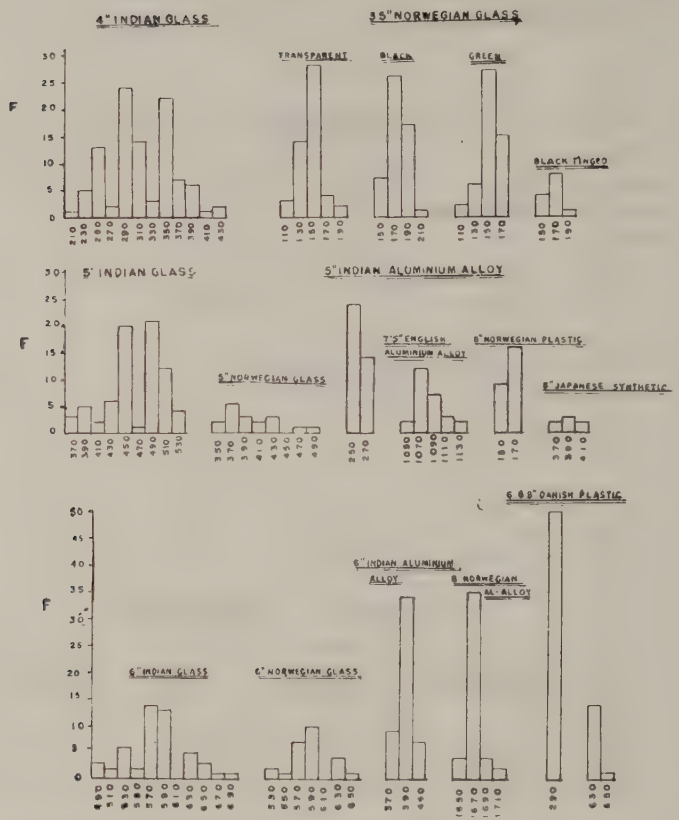
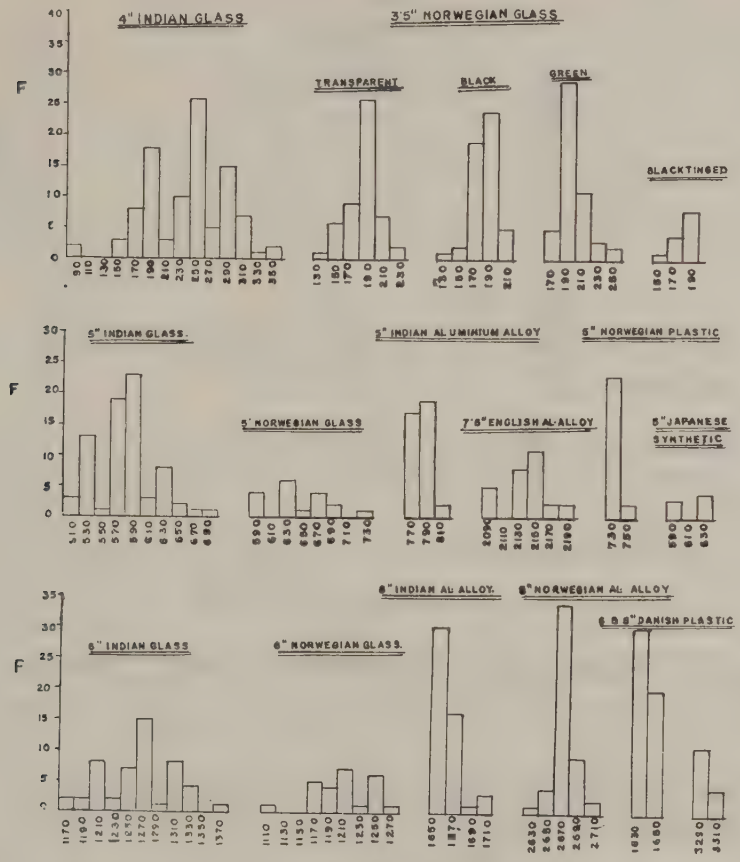


FIG. 4 (*b*). Weight in grams.

DISCUSSION

(*i*) *Diameter*.—For the same size of floats made of different materials, the differences found in the diameter are not significant and the range between lowest and highest is also less. In other words, the floats are uniform as regards diameter.

(*ii*) *Weight*.—It is evident from the tables that among the floats of equal size, glass are the heaviest, metal floats are moderately heavy while plastic ones are light. Among 5″ diameter glass floats, the ones made in India are having much weight followed by Norwegian and Japanese. It is found that the 5″ diameter Japanese synthetic rubber float is heavier than similar sized floats of other materials except Indian and is nearly equal to



4 (*c*). Extra-buoyancy (grams).

FIG. 4. Histogram showing (*a*) Diameter, (*b*) Weight, (*c*) Extra-buoyancy frequency distribution of different floats.

the weight of Norwegian glass float possibly due to that, it is not hollow.

The range of weight in the case of Indian glass float is wide as evidenced by the high standard deviation. Somewhat similar is the case with large-sized Norwegian glass floats, but small-sized ones showed little variation. The range of variation is less in metal as well as plastic with little standard deviation.

As evidenced from the graph (Fig. 5) in logarithmic scales, the weight is proportional to the diameter of the float raised to the power of 2·5. The relation can therefore be represented by the following equation:

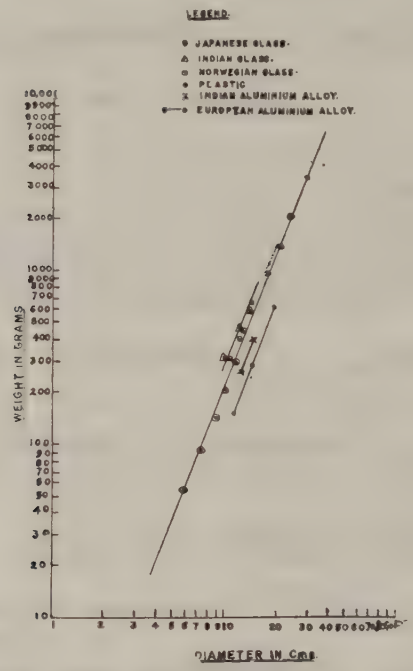


FIG. 5. Graph showing relation between diameter and weights of different types of floats.

$$W = K \times D^{2.5}$$

where W represents the weight in grams, D, the diameter in cm. and K, the constant of relationship.

With the help of graphs (Fig. 6 *a* and *b*) drawn separately for Japanese glass and all other floats, the constants, when worked out, represent the following in each case.

$W = 0{\cdot}29\ D^{2.5}$ for Japanese glass floats,

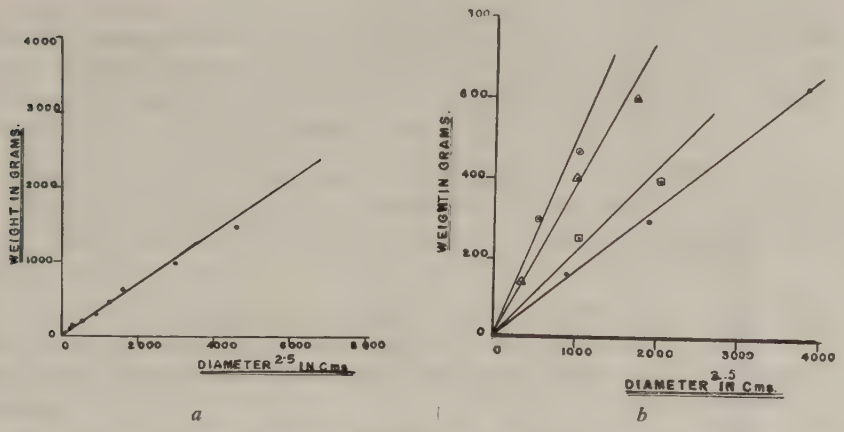
$W = 0{\cdot}48\ D^{2.5}$ for Indian glass floats,

$W = 0{\cdot}37\ D^{2.5}$ for Norwegian glass floats,

$W = 0{\cdot}21\ D^{2.5}$ for Indian aluminium alloy floats,

$W = 0{\cdot}16\ D^{2.5}$ for European plastic floats.

Comparing the values of K, Indian glass float is 1·7 times heavier than Japanese float and 1·3 times than Norwegian glass float. Plastic float is



FIGS. 6 *a* and *b*. Relation between diameter and weight of Japanese glass floats and other floats, namely Indian glass ⊙, Norwegian glass △, Indian aluminium alloy □, and Foreign plastic floats ●.

the lightest of all experimented so far. Indian aluminium float is 56% lighter than Indian glass float.

Extra-buoyancy

The variation or range with respect to extra-buoyancy in all cases is very much similar to their corresponding variation in weight, *viz.*, higher in glass floats, moderate in metal ones and less in plastic.

The extra-buoyancy is considered to be proportional to the cube of the diameter as can be seen from the graphs (Figs. 7 and 8). This relationship can be expressed in the following equation:

$$B = K \times D^3$$

where B denotes the extra-buoyancy in grams, D, the diameter in centimetres and K, the constant of relationship.

The value of 'K' has been worked out as follows:

$B = 0{\cdot}38\ D^3$ for Japanese glass floats,

$B = 0{\cdot}26\ D^3$ for Indian glass floats,

$B = 0{\cdot}33\ D^3$ for Norwegian glass floats,

$B = 0{\cdot}40\ D^3$ for Indian aluminium alloy floats.

$B = 0{\cdot}44\ D^3$ for European plastic floats.

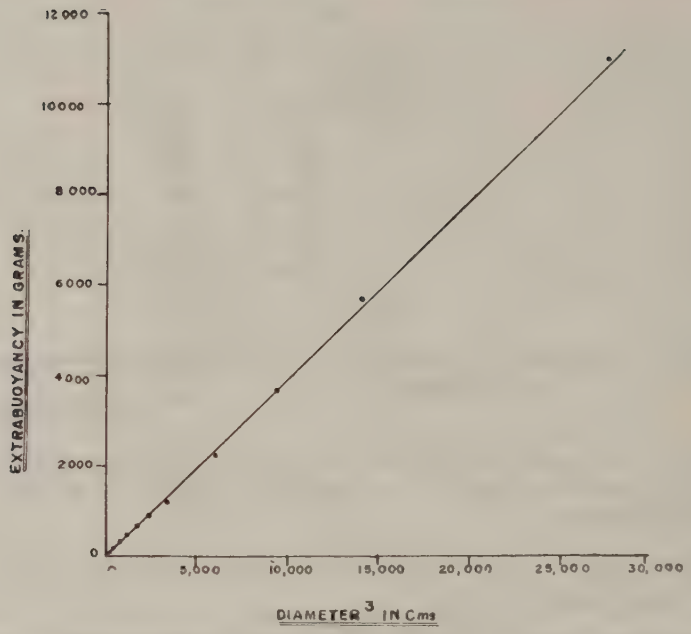


FIG. 7. Relation between diameter and extra-buoyancy of Japanese glass floats.

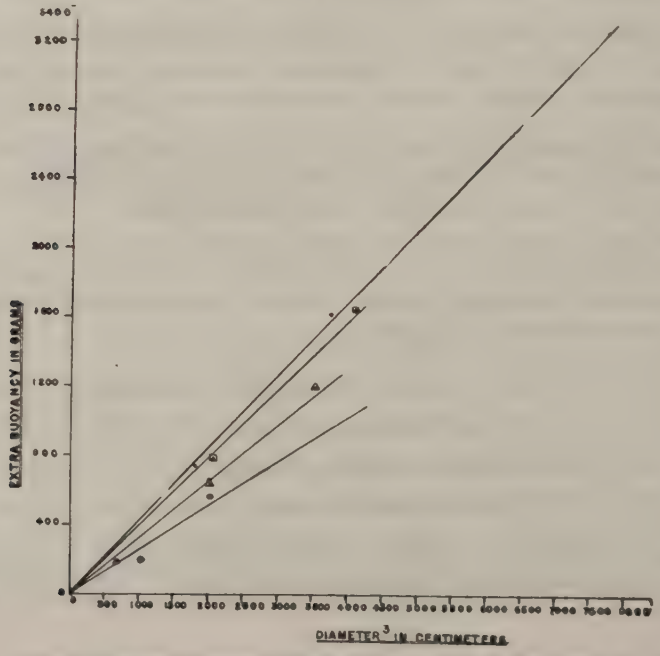


FIG. 8. Relation between diameter and extra-buoyancy of Indian glass ⊙, Norwegian glass △, Indian aluminium alloy □, and European plastic floats ●.

Comparing the values of 'K', the extra-buoyancy of Indian glass float up to 5" diameter size is 68% that of Japanese one and 79% that of Norwegian float. Indian aluminium alloy float has 54% more extra-buoyancy than Indian glass float. The difference in the extra-buoyancy between Indian aluminium alloy and European plastic float is only 10%.

From Table I, it will be seen that the lighter the float, the more is the buoyancy. Accordingly, the extra-buoyancy of the plastic float is found to be higher and next to it, the metallic float has higher buoyancy than the glass float.

From these experiments, it may be seen that the Indian glass floats should be made more uniform in quality and they should be lighter in weight than at present because this is one of the factors which influences the extra-buoyancy.

Summary

Preliminary observations of certain characteristics of some Indian made glass and aluminium alloy floats were attempted and compared with some foreign made floats. The different samples studied and the method employed for finding out the extra-buoyancy are indicated. The data indicate wide variation in weight and extra-buoyancy of different samples.

The relationship between diameter to weight and extra-buoyancy are discussed at length and values obtained for various floats compared. The Indian made glass float is heavier than the foreign float and hence the extra-buoyancy is correspondingly less. The Indian aluminium alloy float is having higher extra-buoyancy than glass ones.

Acknowledgements

I am deeply indebted to Dr. H. Miyamoto, F.A.O./E.T.A.P. Gear Technologist, for guidance and encouragement throughout the course of the work. I am grateful to Shri G. K. Kuriyan and Shri R. Balasubramanyan, Assistant Directors, for going through the manuscript and offering suggestions. I extend my thanks to Officers-in-Charge of Indo-Norwegian Project and Offshore Fishing Station, Cochin, for kindly giving on loan some of the samples of floats included in the investigations.

Reference

*Miyamoto, H. 1952 *The Theory and Practice of Set Nets.*

* Reference is only from the English abstract, which was kindly translated by Dr. H. Miyamoto. Original is in Japanese language.

GOVERNMENT OF INDIA
CENTRAL MARINE FISHERIES RESEARCH STATION, MARINE FISHERIES P.O., MANDAPAM CAMP, SOUTH INDIA

ANNUAL REPORT OF THE CHIEF RESEARCH OFFICER FOR THE YEAR ENDING 31st MARCH 1960

CONTENTS

PAGE

I. ADMINISTRATIVE AND GENERAL 497

II. FISHERY SURVEY 503

III. FISHERY BIOLOGY—

A. *Inshore Fisheries Investigations*

1. Oil-Sardine—*Sardinella longiceps*, and other Clupeoids
   (*a*) At Karwar 507
   (*b*) At Mangalore 509
   (*c*) At Kozhikode 509
   (*d*) At Ernakulam 511
   (*e*) At Neendakara 512
   (*f*) At Mandapam 512
   (*g*) At Waltair 512
2. Mackerel—*Rastrelliger canagurta*
   (*a*) At Karwar 513
   (*b*) At Mangalore 515
   (*c*) At Kozhikode 516
   (*d*) At Ernakulam 516
   (*e*) At Neendakara 517
   (*f*) At Vizhingam 517
   (*g*) At Porto Novo 518
3. Prawns and Lobsters
   (*a*) At Bombay 518
   (*b*) At Mangalore 519
   (*c*) At Kozhikode 519
   (*d*) At Ernakulam 520
   (*e*) At Madras 521
4. Malabar Sole—*Cynoglossus semifasciatus* 522
5. Half-beaks—*Hemirhamphus* spp. 523

PAGE

6. Seer fish—*Scomberomorus guttatus* 523
7. Mullets—*Mugil* spp. 524
8. Tunnies—*Katsuwonus pelamis* 525
9. Molluscs 526

B. *Offshore Fisheries Investigations*
(*a*) At Bombay 526
(*b*) At Ernakulam 531
(*c*) At Tuticorin 535
(*d*) At Waltair 536
(*e*) At Calcutta 536

C. *Physiology and Marine Fish Farming* 539

IV. MARINE BIOLOGY—

A. *Planktological Investigations*
(*a*) At Kandla 540
(*b*) At Karwar 540
(*c*) At Mangalore 541
(*d*) At Kozhikode 542
(*e*) At Mandapam 543
(*f*) At Madras 544

B. *Oceanographical Studies*
(*a*) At Bombay 544
(*b*) At Karwar 545
(*c*) At Mangalore 545
(*d*) At Kozhikode 545
(*e*) At Ernakulam 546

C. *Algology* 548

V. LIST OF PUBLICATIONS DURING THE YEAR 1959–60 549

I. ADMINISTRATIVE AND GENERAL

Progress in the various activities of the Headquarters Research Station and the different subordinate set-ups all along the coastline of India kept steady pace during the year 1959–60. A Research/Survey Centre was established at Cannanore, the collection of data and material from the Minicoy-Laccadives area was continued and a preliminary study was made of the fishery resources of the Andaman and Nicobar area with a view to setting up a Research Unit there. Systematic studies and collection of data

on the economically important fishes were continued at all the important fishery centres. The fishery for the mackerel and the oil sardine, which are the two major forms of commercial importance, proved to be erratic again this year. Against the 1958 landings of about 1¼ lakh tons each the 1959 catches of mackerel and oil sardine came to less than ¾ lakh tons each. Several of the other major groups also registered a decline in yield with the result that total landings of marine fishes in 1959 was only 5·8 lakh tons as against the 1958 figure of 7·6 lakh tons. The decline in the figures would have been more marked but for the improved yields in some of the minor fisheries and the encouraging results obtained in the power fishing operations especially at Bombay. Proposals for the expansion of the Research activities of the Station during the Third Five-Year Plan were formulated and accepted in principle by Government. Volume VI, No. 2 of the *Indian Journal of Fisheries* was published during the year.

The Budget allotment for the year under the heads recurring and non-recurring amounted to about Rs. 14 lakhs. The completion of the Guest House and provision of furniture for the same, provision of barbed wire fencing and installation of a few bore-well pump sets for supply of freshwater to the new colony and the Guest House were the major items of capital work carried out during the year. Renovation of the three blocks of thatched hutments in the campus was also sanctioned.

The annual requirements of scientific equipments and materials were duly purchased and made available to the scientific workers at different centres. A consignment of about 100 items of chemicals and stains have been sent to the Central Fisheries Technological Research Station (Processing Wing) at Ernakulam as a permanent transfer. A Willy's jeep with trailer and a Dinghy have been procured for use at the Ernakulam Substation. Two pablo boats for use at the Karwar and Vizhingam Research Units, indents for which were placed with the Director-General of Supplies and Disposals, are still to be received. Two Seffle Marine Diesel Engines and an outboard motor transferred to this Station under the T.C.M. Programme have been duly received. A generating set was procured for light fishing experiments.

The Library of the Research Station was considerably augmented by the addition of some rare and new books and publications, maps, etc., and by increasing the number of periodicals subscribed for. Considerable additions have been made also by exchange of publications for the *Indian Journal of Fisheries*. The Institution was enrolled as a member of the Connemara Public Library Madras. Active steps were taken to improve the Library

facilities at the various subordinate establishments by the permanent transfer of publications, circulation and by loan of books and periodicals from the Headquarters station.

For the implementation of the Laccadives Fisheries Research Scheme one post each of Assistant Research Officer (Tuna), Research Assistant, Field Investigator, Field Assistant, Lower Division Clerk, Laboratory Boy and Peon was sanctioned. To cope up with the increased volume of work in the Library an additional post of Librarian was created. A post of watchman was also created for the Karwar Research Unit.

The following appointments of Research Officers and Assistant Research Officers were made:

Dr. R. Subrahmanyan	..	Research Officer (Marine Biology)
Shri V. Sadasivan	..	Research Officer (Fishery Naturalist)
Shri M. S. Prabhu	..	Research Officer (Sardines)
Shri K. Virabhadra Rao	..	Research Officer (Fishery Survey)
Shri C. Mukundan	..	Assistant Research Officer (Pelagic Fisheries)
Miss P. D. Nayak	..	Assistant Research Officer (Sardines)
Dr. A. K. Nagabhushanam	..	Do. Do. (Offshore Fisheries)
Shri M. Narayankutty	..	Do. Do. (Do.)
Shri K. N. Krishna Kartha	..	Do. Do. (Do.)
Shri Debidas Chakraborthi	..	Do. Do. (Statistics)

Shri P. C. George, who earlier joined the post of Research Officer (Fishery Survey), reverted to his regular post when Shri K. Virabhadra Rao assumed charge of that post.

Dr. S. Jones was confirmed in the post of Chief Research Officer with effect from 26-4-1957. Dr. R. Viswanathan, Shri P. R. Sadasivan Tampi, Shri L. R. Kasturirangan and Shri S. V. Bapat were also confirmed in the posts of Research Assistants (Selection Grade).

Dr. (Mrs.) F. Thivy, Assistant Research Officer (Marine Algology), superannuated from Government service on the afternoon of the 5th October 1959. She was re-employed in the same post for a period of one year from the 6th October 1959. Shri N. K. Velankar, Research Officer (Chemist), was transferred to the Central Fisheries Technological Research Station, Ernakulam, along with the post held by him.

Dr. S. Jones, Chief Research Officer, participated in the meetings of the Fishery Research Committee at Trivandrum in April 1959 and at New Delhi in December 1959. He attended the Conference of Heads of State Fisheries Departments held at the Ministry of Food and Agriculture, New Delhi in April and June 1959, for formulating the Fisheries Developmental Plans under the III Five-Year Plan. He also attended the meeting of the National Board of Fisheries held at New Delhi, in December 1959. Other important meetings in which he participated during the year were the first meeting of the Standing Committee of the Indo-Norwegian Project held at Quilon, the Madras State Fisheries Advisory Board held at Madras, Second Meeting of the Committee for Oceanography of the Central Board of Geophysics held at Ernakulam and the first All-India Congress of Zoology held at Jubbalpore.

Dr. R. Raghu Prasad, Research Officer (Marine Biology) was deputed to participate in the cruise of the Soviet Oceanographic Research Vessel "Vitiaz" in the Indian Ocean. Dr. Prasad embarked on the Research Vessel at Cochin early in February 1960 by which time "Vitiaz" had already covered 124 stations in the Indian Ocean. He remained on board the ship for a period of two months during which it covered 97 stations over a distance of 8,200 miles and visited (1) Male (Maldives), (2) Tamatave and Nossi-Be (Madagascar), (3) Dzaudozi (Comore Island), (4) Zanzibar and (5) Mahe (Seychelles). Dr. Prasad disembarked from the ship at Bombay on the 4th April 1960. Dr. Prasad's participation in the cruise had afforded a further opportunity to study the organization and work of a large-scale oceanographic expedition and to get first-hand knowledge of the various techniques in Oceanography developed by foreign scientists. The studies on primary production and plankton made by Dr. Prasad on board the vessel have revealed that in the equatorial region of the Indian Ocean there are areas of very high production and some of these areas are now being exploited by Japanese fishermen. During this cruise many species of deep-sea fish formerly reported from the Pacific and the Atlantic Oceans were also recorded from the Indian Ocean.

Shri K. Virabhadra Rao who was deputed to Japan for specialized training in Molluscan fisheries returned to India in October 1959. Shri S. K. Banerjee, Research Officer (Fishery Survey), was sent to U.S.A. for advanced training in Fisheries Statistics under T.C.M. and he returned to India in March 1960. Dr. R. Viswanathan, Assistant Research Officer (Oceanography), participated as a Trainee in the International Training Course in the use of Radioisotopes in Agricultural Research at New Delhi. Dr. R.

Subrahmanyan, Dr. (Mrs.) F. Thivy and Dr. R. Prasanna Varma participated in the Symposium on Algæ arranged by the UNESCO and Indian Council of Agricultural Research at New Delhi.

Shri K. K. Parameswara Menon, Field Assistant in this Department, was awarded a prize of Rs. 500 in the competition held by the Ministry of Education for books for neo-literates for his article in Malayalam "Katalum Manushanum" (Sea and Man). Dr. G. Seshappa and Shri S. T. Nagarathinam received cash awards for their good performances in the Hindi Probodh Examination conducted by the Home Ministry in December 1958. Owing to the Hindi Instructor leaving the Department in October 1959 the Hindi Classes held at this Station have been temporarily suspended.

Mr. V. M. Naumov, a Russian Fisheries Expert, has been assigned by the F.A.O. for work in India and he has been engaged in Offshore Fisheries investigations at the Waltair Research Unit of this Station since October 1959. Shri V. Sadasivan, Research Officer, has been put as his understudy and Shri B. Krishnamurthy and Dr. A. K. Nagabhushanam, Assistant Research Officers, have also been instructed to work in close collaboration with the expert.

Dr. Karl Banse, a German Scientist who was working at this Station as a Scholar under the Indo-German Industrial Co-operation Scheme, left for Germany in February 1960 after successfully completing his work here. Shri K. K. Tandon who was also working as a Senior Research Scholar under the Ministry of Scientific Research and Cultural Affairs Research Training Scholarship Scheme completed his 3 years' course in March 1960 and submitted the results of his work here as a Thesis for the Ph.D. Degree of the Punjab University. On his selection to the Junior Fellowship under the Council of Scientific and Industrial Research tenable at this Research Station, Shri P. S. B. R. James, Senior Research Scholar, relinquished the scholarship to take up the fellowship. Shri M. Subrahmanyan who was also working as a Senior Research Scholar was relieved during the year for taking up an appointment elsewhere. Dr. E. G. Silas joined as an Honorary Research Worker at this Station in July 1959.

The Southern Zone Study Group of the Estimates Committee of the Parliament visited this Research Station in July 1959 and studied in detail various aspects of work and activities, staff and budget allocations, etc. The Zoological Review Committee of the University Grants Commission headed by Prof. J. B. S. Haldane visited the Research Station in September, 1959 for assessing the facilities in Marine Biological work that could be made available by the Research Station to University workers.

Shri B. Ramakrishna Rao, Governor of Kerala, visited the Kozhikode Substation in December 1959. Among distinguished visitors to the Headquarters Station may be mentioned Shrimathi Lourdammal Simon, the Madras State Minister for Fisheries, Dr. M. S. Randhawa, Vice-President, Indian Council of Agricultural Research, New Delhi, Dr. L. Beatty, Canadian Fisheries Expert on Fisheries Technology, Mr. Krog Hansen, Director Indo-Norwegian Project, Mr. Klaus Sunnana, Fisheries Leader, Indo-Norwegian Project, Dr. Rudolf H. Fritsch, Acting Director, UNESCO Office, New Delhi, Mr. M. Virat of the Pondicherry Research Institute, Shri M. R. Bhide, I.C.S., Secretary to the Government of India, Ministry of Community Development (Department of Co-operation), New Delhi, Shri P. A. Copalakrishnan, I.C.S., Chairman, Life Insurance Corporation of India, Prof. M. S. Thacker, Director-General of Council of Scientific and Industrial Research, Shri Y. D. Gundevia, I.C.S., Indian High Commissioner in Ceylon, Shri A. C. Mukerji, General Manager, Southern Railways, Prof. K. S. G. Doss, Director, Central Electro-Chemical Research Institute, Karaikudi, Shri D. N. Banerji, Member, Central Board of Revenue, Shri R. N. Misra, Director of Inspections, Customs, New Delhi, Shri I. V. Ranga Rao, Field Officer, Small Industries Service Institute, Madras, Shri E. C. P. Prabhakhar, I.A.S., Collector of Ramanathapuram, Prof. A. B. Misra, Head of the Department of Zoology, Banaras Hindu University, Shri Ramakrishnan, Deputy Secretary, Council of Scientific and Industrial Research, New Delhi, Dr. Siro Kawaguti, Professor of Marine Biology, Okayama University, Japan, Shri E. B. Tissevera Singhe, Chairman and Director of the National Salt Corporation, Colombo, Shri M. Miskeith, Superintending Engineer, Deep Sea Fishing Station, Bombay and Mr. Rodney Jonklaas, Underwater Expert from Ceylon while Mr. Egil Via, Norwegian Fishery Expert, Shri K. Gopinath Pillai, Director of Fisheries, Kerala, Shri P. Ananthanarayanan of the State Trading Corporation, New Delhi and Shri P. Thomas Deputy Director Ministry of Food and Agriculture (Department of Agriculture and Deputy Storage Adviser), Central Warehousing Corporation visited the Kozhikode Substation.

The number of visitors to the Research Station showed a substantial increase during the year. The two Dugongs kept in the Aquarium proved to be objects of special interest as this is the unique instance of Dugongs being reared in captivity in any part of the world. Large number of enquiries received from various sources have been answered and detailed information supplied to the parties. At the instance of the Ministry of Food and Agriculture, a detailed study of the effects of the Kayankulam Kayal Reclamation Scheme in Kerala State on the Fisheries of that area was carried out by the Research Officer (Prawns) and a report embodying the results thereof

was submitted to the Government of India. The Research Station actively participated in the World Agricultural Fair organised by the Government of India at New Delhi. An exhibition was organized at the Research Station in December 1959 on the occasion of the celebration of the tenth anniversary of the Mandapam Branch of the Zoological Society of India. The various collaborated schemes and experiments and other activities referred to in the previous year's report were all continued actively except that the Nursery School at the Institution had to be closed down for want of adequate financial support. A list of scientific papers published during the year is given at the end of this report.

II. Fishery Survey

The analysis of data collected in 1959 was completed during the year and the total landings of marine fish during 1959 was estimated as 584,193 m. tons as compared to 755,774 m. tons in 1958, showing a decrease of about more than 0·17 million m. tons. The State-war break-up of the total landings for 1959 and 1958 are given in Table I.

Table I

States	Fish landings in metric tons	
	1959	1958
1. West Bengal and Orissa ..	3,962	6,267
2. Andhra ..	29,464	28,846
3. Madras ..	103,497	118,056
4. Kerala ..	191,375	294,655
5. Mysore ..	52,825	80,242
6. Bombay (including Saurashtra and Kutch) ..	198,192	222,886
7. Andaman and Nicobar ..	123	92
8. Mechanised vessels ..	4,755	4,730
Total ..	584,193	755,774

All the States showed a decline in production excepting Andhra. The landings from mechanised vessels registered an increase over the last year's

figures. The most significant decline in the catches had been in West Bengal and Orissa, Kerala and Mysore. The decline in Madras and Bombay were not significant.

The landings in West Bengal and Orissa were about two-third of those of 1958. This was mainly due to the decline in catches of prawns and other crustaceans, other clupeids, ribbon fish, other sardines and pomfrets. Despite the increase in perches, mackerel, and *Leiognathus* landings, the overall decrease was not balanced.

In Andhra State, the landings of ribbon fish and *Leiognathus* were nearly double those of 1958. Prawns and other crustaceans showed an increase of 20% and there was good landing of oil sardine during 1959 as compared to 1958 thus showing an overall increase in total landings in spite of decrease of landings of *Caranx* by 82% and of other clupeids, pomfrets, other sardines and *Anchoviella* (whose percentages of decrease varied between 10 and 37).

In Madras State, the landings of *Anchoviella*, ribbon fish, *Lactarius* and *Caranx* showed some decrease, the percentages of decrease varying from 19 to 41. On the other hand, the landings of Penæid prawns and other crustaceans, other clupeids and pomfrets increased by 52%, 41% and 36% respectively. Similarly the landings of flying fish, mackerel and *Thrissocles* were nearly 500%, 250% and 200% respectively over those of 1958. Even then, the total landings of the State declined by 12%.

The heavy decline in the landings of Kerala is due to the failure of mackerel and sardine fisheries which accounted for 90% of the net fall in the landings. The landings of oil sardine were nearly half of the last year's catches, while mackerel landings showed a decline by 56%. The catches of *Anchoviella*, *Thrissocles*, and other clupeids registered an increase during the year, but the total increase was too meagre to compensate the heavy deficiency due to failure of sardine and mackerel fisheries.

In the State of Mysore, landings of oil sardine, and cat fishes were 7 and 3 times the respective landings of 1958. Landings of *Thrissocles*, *Anchoviella*, Penæid prawns and *Leiognathus* showed significant increase but the complete failure of mackerel lowered the overall landings. Out of the gross decrease of 39,661 m. tons, mackerel alone accounted for 36,033 m. tons during the year.

The decrease in landings in Bombay State (including Saurashtra and Kutch) was mainly due to the fall in respect of landings of prawns and other crustaceans and Bombay duck and to some extent by the fall in the landings

of cat fish, ibbon fish, Sciœnids and eels. The landings of mackerel, polynemids, pomfrets and other clupeids, etc., showed some increase during the period, but these could not compensate for the deficiency caused by the fall in the landings of the previously mentioned fishes, the net short fall being of the order of 24,000 m. tons.

The salient features of 1959 fisheries were:

(*a*) Unlike last year, the mackerel fishery was a complete failure during the year. Mackerel alone accounted for 31% of the gross decrease during the year. Barring Bombay which showed some increased landings, the mackerel landings showed considerable decline in Kerala and Mysore.

(*b*) Oil sardine fishery also showed a significant decrease which was due to the fall in landings in Kerala, Bombay and Madras States. This fishery accounted for 27% of the gross decline.

(*c*) Decrease was witnessed in the landings of Bombay duck, *Anchoviella*, Sciænids, perches, *Caranx*, *Lactarius*, seer fish and sole, the percentages of decrease varying between 15 and 46.

(*d*) The low landings of ribbon fish accounted 5% of the gross fall.

(*e*) The landings of flying fish were nearly 3 times those of last year. This was due to heavy landings in Madras State.

(*f*) *Thrissocles* also showed a significant increase which was mainly contributed by Madras, Kerala and Mysore States.

(*g*) The catches of other clupeids followed by polynemids showed an increase due to the higher contribution of the States of Madras, Kerala, Bombay and Mysore.

Table II shows the overall composition of the total fish landings in India during 1959. For comparison, the corresponding figures of 1958 are also given.

Catch per unit of effort.—Table III shows the total effort in man-hours expended in each State and also the catch in kg. per man-hour. The corresponding figures for 1958 are also shown for comparison.

Table I I shows that both the total effort as well as the catch per unit of effort during the period 1959 were less than those of 1958. Barring Madras, all States put less effort during the year than the last year. An increase of catch per unit of effort was witnessed in respect of West Bengal and Orissa, Andhra and Bombay while the others showed a decline.

TABLE II

Composition of fish landings

	Name of fish	Quantity landed in metric tons	
		1959	1958
1.	Elasmobranchs	23,446	24,286
2.	Eels	6,076	9,159
3.	Cat fishes	20,272	29,872
4.	*Chirocentrus*	5,428	5,549
5.	(*a*) Oil sardine	69,234	123,731
	(*b*) Other sardines	41,167	39,958
	(*c*) *Hilsa ilisha*	844	991
	(*d*) Other *Hilsa*	3,046	2,660
	(*e*) *Anchoviella*	24,477	29,346
	(*f*) *Thrissocles*	8,108	3,960
	(*g*) Other clupeids	21,211	15,525
6.	(*a*) Bombay duck	57,210	67,188
	(*b*) *Saurida*	597	238
7.	*Hemirhamphus* and *Belone*	383	348
8.	Flying fish	1,668	388
9.	Perches	9,389	11,959
10.	Red Mullets	1,526	2,166
11.	Polynemids	7,666	5,974
12.	Sciænids	20,442	25,565
13.	Ribbon fish	31,830	41,918
14.	(*a*) *Caranx*	9,773	18,133
	(*b*) *Chorinemus*	2,658	3,014
	(*c*) *Coryphæna and Elacate*	471	820
	(*d*) *Trachinotus*	2	59
15.	(*a*) *Leiognathus*	13,200	12,865
	(*b*) *Gazza*	293	343
16.	*Lactarius*	13,842	16,363
17.	Pomfrets	17,389	16,587
18.	Mackerel	62,198	123,282
19.	Seer fish	6,590	7,889
20.	Tunnies	2,866	3,239
21.	*Sphyræna*	972	830
22.	Mullet (*Mugil*)	245	729
23.	*Bregmaceros*	3,821	3,884
24.	Soles	10,360	12,856
25.	(*a*) Penæids prawns	27,632	29,204
	(*b*) Non-penæid prawns	37,805	55,987
	(*c*) Other crustaceans	2,092	1,508
26.	Miscellaneous	17,964	7,401
	TOTAL ..	584,193	755,774

TABLE III

Total effort in man-hours and catch in kg. per man-hour

States	Effort in 1,000 man-hours		Catch in kg. per man-hour	
	1958	1959	1958	1959
1. West Bengal and Orissa	9,733	4,787	0·64	0·83
2. Andhra	50,628	47,436	0·57	0·62
3. Madras	66,149	69,166	1·78	1·50
4. Kerala	95,391	63,328	3·09	3·02
5. Mysore	10,809	10,271	7·42	5·14
6. Bombay (including Saurashtra and Kutch)	80,545	52,391	2·77	3·78
TOTAL ..	313,255	247,379	2·40	2·34

A slight change in the method of collecting fish landing data was introduced in Kerala from July 1959. The same was introduced in Mysore from August 1959 and in Bombay from September 1959. Under this new scheme, instead of collecting data at fixed centres, the selection of landing centres was made at random. This permitted the calculation of estimate of sampling error of the estimate of landings. The error in the estimate of landings for the west coast of India during the last quarter of 1959 was estimated at 7%. The per cent. error of the annual estimate (which will be calculated from 1960) is likely to be lower than this.

III. FISHERY BIOLOGY

A. *Inshore Fisheries Investigations*

1. *Oil Sardine* (Sardinella longiceps) *and other Clupeoids*

(*a*) *At Karwar*: *Sardinella longiceps*.—A total of 141·789 m. tons were landed for the year 1959-60 in contrast to 90·706 for the year 1958–59. About 99% of the total catch of oil sardine was accounted for by the *rampan* nets. The catch-per-unit of effort for *yendi*, *rampan* and cast nets were respectively 0·629 kg., 2·106 kg. and 2·142 kg.

In April 1959 the size-range was 130–97 mm. with the 175 mm. size-group predominating. All specimens were found in the earlier stages of

maturity, not beyond stage II, and the two sexes were found to be in about the same numbers. This year's fishery commenced during the second week of November 1959 and lasted only for two months. The fish in the commercial catch varied in total length from 121–68 mm. with the 135 mm. and 145 mm. size-groups dominating for November and December respectively. Based on length-frequency studies, it is inferred that about 88% of the fish have their total lengths confined within the range of 130–49 mm. group and that the specimens were immature, the stages of maturity being I and II. The range of ova varied from 0·017–0·170 mm. with the peak at 0·068–0·085 mm. It was noted that the females formed slightly a higher percentage in all the size-groups except in 130–39 mm. The feeding was found to be moderate, and the fish did not appear to abstain from feeding.

Sardinella fimbriata.—The 'pedi' fishery commenced at Karwar towards the third week of September and the peak period was noticed in October. The total quantity landed at Karwar during the year was 12,679 kg. in contrast to 11,398·9 kg. for 1958–59. The fishes were encountered in *yendi*, cast nets, *gorbalæ* (drag net) and *rampan*, the latter two types used exclusively for the capture of 'pedi' shoals.

A continuation of the 1958–59 season was noticed up to June 1959. The minimum and maximum size recorded during September–March were 71 mm. and 146 mm. respectively. A progressive shifting of the mode month by month was noticed for the year, indicating that the fish had added about 30 mm. to their length in seven months' time. The monthly increment in length during the fishing season of 1959–60 thus appeared to be more or less the same as what was observed in 1958–59. It was also seen that the 110–29 mm. size group (immature ones in stages I and II) contribute much to the fishery and that the fishery was composed of one-year-old individuals. Smaller crustaceans figured prominently in the stomach analysis. *S. fimbriata* from the different centres of North Kanara are being collected and analysed.

Hilsa ilisha.—An exceptionally good catch of the Indian shad was noticed for October–November, the landings for the respective months being 5741·322 kg. and 2038·50 kg. In January 45·3 kg. were landed in one *rampan* net. About 98% of the total catch was brought by the *rampan* net. The modal size for October, November and January varied from 240–59, 240–59 and 280–99 mm. respectively. Length-frequency studies revealed that about 30% of the fish were within the range of 240–59 mm. and that the growth of the fish between November and January is about 40 mm. and it is assumed that the fish which contributed to the fishery belonged to the

same group. The fishes examined were immature. Species of *Oithona*, *Evadne*, *Acartia* and *Acrocalanus* formed the majority in the gut, and other minor forms noticed were copepod eggs, appendages of copepods, species of *Coscinodiscus*, *Penilia*, *Paracalanus*, *Cypris* larvæ, fish eggs and fish scales.

Opisthopterus tardoore.—The *pachki* fishery commenced in June and lasted up to September, the peak period was in August. A total of 886·521 kg. were netted (all by *yendi* operation) during the year, the size-range in the commercial catches being 61–162 mm. The 99 mm. size-group dominated the catch throughout the season in contrast to the two modal sizes of 99 and 149 mm. during the 1958–59 season.

(*b*) *At Mangalore*.—The oil sardine fishery in the area around Mangalore was very poor during this year as in the previous year. The fishery started in late October and ended abruptly by the close of December except for stray catches in January and February 1960. At Ullal the total annual catch was about 55·84 metric tons of which nearly 55·7 m. tons were landed in November. The entire catch in November was accounted for by cast net and *Chalavala* (gill-net), and of these two the gill-net recorded the higher catch per unit of effort (3·24 kg.).

Length-frequency analysis showed that the catches were supported mostly by a single age group. The modal size of this year-class was 125–29 mm. in October and it shifted to 145–49 mm. in February 1960. The dominant size-groups recorded by the various nets from October 1959–February 1960 were either the same or differed only to the extent of 5 mm.

In August, a few oil sardines obtained from *rampan* landings were found to be in spent condition. From October–January the fish were mostly immature (stages I and II) whereas in February stage III was recorded.

The food items of oil sardine consisted mainly of diatoms of which *Fragilaria oceanica* and species of *Coscinodiscus*, *Biddulphia*, *Thalassiothrix*, *Pleurosigma*, *Nitzschia* and *Rhizosolenia* were the important forms. Other items were the dinoflagellates, *Ceratium massiliensis*, *C. fuses*, *C. tripos*, tintinnids and copepods.

Sardinella fimbriata.—*S. fimbriata* were landed in small quantities in the Mangalore area. In the monthly commercial catches of the various nets there was only a single modal length group. The fish were mostly immature (stages I and II), during the November–March period.

(*c*) *At Kozhikode*.—The oil sardine fishery at Calicut during the year 1959–60 was poor; the total landings being only 1,561·16 m. tons as compared to 4,062·68 m. tons in 1958–59. More than 85% of the oil sardine

catches were landed within a period of 7 months, from August 1959–January 1960 with the highest catch in October 1959 when 539·7 m. tons were landed. A general upward trend in the oil sardine landings was noticed during the first three-quarters of the year (April–June to October–December 1959). The fishery continued up to January 1960 but came to an abrupt end by February.

Among the different gears operated for oil sardine *kolli vala* (*patten kolli* and *mathi kolli*) and *thattum vala* (boat-seines) had accounted for 72·8% and 25·11% of the total landings with 72·8% and 22·93% of the total effort respectively. Of all the gears, *kolli vala* consistently dominated in the fishing activity during the year and the CPUE (Catch per unit of effort) for this gear (9·21) was the highest. Next in importance was *thattum vala* for which the CPUE recorded was 5·53. However, the general decline of the oil sardine fishery during the year had, to a great extent, reflected on the overall low CPUE of the various gears.

The range in size of the oil sardine caught at Calicut varied from 90–179 mm. A study of the size and age composition of the oil sardine indicated the following: (1) the fishery in general was supported by three different year-classes, the modal sizes of which were around 100, 140 and 175 mm., (2) the second and third year-classes had dominated the fishery up to August 1959, (3) the new year-class had entered the fishery in September 1959 and (4) from October 1959 onwards the 130–40 mm. group was dominant and the entry of this group had resulted in the increased yield of oil sardine during the period from October 1959–January 1960. However, from the general decline of the oil sardine fishery from 1957–58 to 1958–59, it has to be inferred that the level of annual recruitment during the past two years had been very low.

Some of the other notable features concerning the oil sardine fishery were: (1) the occurrence of denser shoals within the 10 fathom area (mostly 4–8 fathom region) during the peak season and (2) the entry of the smaller size-group (140–50 mm.) into the fishery about a month earlier than during the previous season. In August, September and October fish ranging in size from 166–90 mm. quickly advanced in their stages of maturity from stage IV to stage VII. Although the fishery for the indeterminates and immature juveniles started in September, it assumed importance only after the middle of October. Analysis of sex ratio showed that while males were always more, with a ratio of 1·7: 1 in the mature group than in the immature group where the ratio was 1·3: 1.

Preliminary observations on the fat variations in the immature individuals of the oil sardine indicate that there is a higher percentage of fat storage around the visceral organs than in the muscles and that there seems to be more fat in the smaller fishes than in larger ones.

The stomachs of *S. longiceps* 120–84 mm. in length collected by different types of nets operating at depths ranging from 4–11 meters were examined from November-February. Bacillariophyceæ was more abundant than the other forms. *Fragilaria oceanica* contributed the most to the food in all the months. Myxophyceæ was represented by *Trichodesmium thiebauti* while several forms of Dinophyceæ were also present. Among the zooplankters, tintinnids, crustacean eggs, nauplii and copepods were common while *Evadne* sp., *Lucifer*, the zoea and cypris stages of *Lepas* and fish eggs were rare.

Sardinella fimbriata.—*S. fimbriata* examined from January–March 1960 showed that all of them were in stage I of maturity with the sex ratio of 1 : 1·4, the females being more. The size ranges were from 117–46 mm. and 124–56 mm. in January and February respectively with the dominant group of 125–29 mm. of January shifting to 130–34 mm. in February.

(*d*) *At Ernakulam: Sardinella longiceps.*—Work on scales of the oil sardine was continued during the year. The material was collected from Manassery and Kannamali. The ranges in size of the sardine examined during the first, second, third and the last quarter were 165–85, 165–90, 170–85 (and also 130–45) and 130–45 mm. respectively. Majority of the sardine examined possessed well-defined rings in their scales. The sardine (collected from Manassery) measuring 165–85 mm. in total length possessed 2 rings in their scales, the second one being close to the margin while those of 130–45 mm. in length had one ring in their scales (in fish collected from Kannamali). Otoliths from these sardine samples were also collected and are being examined in detail.

Length-frequency data collected during the first quarter showed that modes ranged from 150–75 mm. The range of maturity stages in April, May and June were I–II, II–IV and II–V respectively. During the same months, the percentage compositions of females were 38·0, 64·0 and 70·0 respectively. The sardine fishery was poorer in April and June than in May. Fishing operations were adversely affected by monsoon in June. *Thangu vala* (boat-seine) and *Chala vala* (gill-net) were the nets operated (in the 3–7 fathom area) for catching the sardine. During the second quarter the total length of fish showed a range from 80–195 mm. The occurrence

of juvenile sardine of modal length at 80 and 100 mm. was quite interesting. In August and September, the females formed 53·0 and 48·0% respectively.

(*e*) *At Neendakara.*—Studies on the length-frequency, sex, stage of maturity, feeding baits and growth indic s of *Sardinella longiceps* were continued during the year. The fish ranged in size from 125 mm. and 195 mm. Specimens belonging to stage III and stage IV appeared in May, June and July, while specimens examined during other months were all immature, belonging to stages I and II. Mature or spent specimens were not found at these landing places during the year.

(*f*) *At Mandapam.*—The popular "torch fishing" for *Choodai* in Palk Bay near Mandapam was almost absent during the year. Only three boats at Thangachimadam were engaged in "torch fishing" and landed small quantities of sardines. Regular *Choodai* fishing in Palk Bay commenced in May and lasted till October. In the Gulf of Mannar the fishery started in November and was continued till March. Fairly good quantities of sardines were landed in the Palk Bay centres while the fishery was rather poor in the Gulf of Mannar. As in the case of the previous year *S. albella* formed the dominant catch in Palk Bay with *S. gibbosa* as second in importance. A reverse trend was noticed in the Gulf of Mannar. Small quantities of *S. clupeoides* Blkr., a species hitherto not recorded in India, were found occurring regularly at Rameswaram Road fishing centre.

S. albella from 35–120 mm. entered the fishery in Palk Bay while fish of 65–105 mm. were found occurring in the Gulf of Mannar. The size range of *S. gibbosa* was 35–125 mm. for the Palk Bay and 72–110 mm. for the Gulf of Mannar. Data on population studies based on morphometric characters are under consolidation. Regular observations were made on food and feeding habits, age composition and maturity stages.

(*g*) *At Waltair.*—The sardine fishery at Lawson's Bay was poor during the year 1959–60. The estimated total landings of sardines for the period March 1959–February 1960 was about 36·79 m. tons forming only 5·89% of the total fish landings at this place. 98·48% of the total catch of sardines were by gill-nets and the rest by shore-seines and boat-seines. The maximum catch landed in March 1959 was 21·58 m. tons and the next highest catch of 10·97 m. tons was recorded in July. The 1959–60 fishing season for sardines commenced in October and the fishery was very poor as only 2·69 m. tons were landed during the period October–February. *Sardinella fimbriata* was the predominant species. The fishery was supported mainly by the juveniles and immature fish. *Sardinella gibbosa* was caught in considerable quantities in April, May and February. A third species, *Sardinella sirm*

was observed in the catches at Lawson's Bay for the first time during April and May. Studies on the biology of *S. fimbriata* and *S. gibbosa* were continued. Gut contents of *S. fimbriata* of different length groups indicated that in general, larger fish fed on bigger crustaceans such as *Acetes*, *Lucifer* and larval decopods along with post-larval fishes. Smaller fish fed chiefly on copepods, larval molluscs and *Coscinodiscus*. *Trichodesmium* was also observed in many stomachs. Copepods formed the chief food of *S. gibbosa*. Specimens of *S. fimbriata* examined in June and July ranged in size from 146–90 mm. and they were in stages I–III of maturity. The fish examined during October–February were all juveniles. Specimens of *S. gibbosa* examined during April and May were either juveniles or in stage I while fish in stages II, III and IV were observed in February. During June and July the fishes ranged in size from 146–90 mm. with 165 and 180 mm. groups dominant in the respective months. During November–January they ranged from 32–102 mm. with 40 and 45 mm. and 80 and 75 mm. as dominant size-groups during November, December and January respectively. *S. gibbosa* ranged from 60–135 mm. with 75 and 100 mm. groups dominant in April and 110 and 125 mm. groups dominant in May. Meristic counts and morphometric measurements were taken of various samples. The data collected are under analysis.

2. *Mackerel*—Rastrelliger canagurta

(*a*) *At Karwar*.—The 1958–59 fishery of the Indian mackerel continued till the middle of April 1959. Since the last decade this was the first occasion that such a prolonged fishing season extending for about seven months was observed. With the total catch of 37·82 m. tons in April 1959, the 1958–59 season yielded a total of 2,744·2 m. tons which is the highest recorded figure. The fishery during 1959–60 was, however, a total failure all along the North Kanara coast. At Karwar, the fishery commenced with the first operation of *rampan* (boat-seine) on 23–10–1959 and lasted till the end of February 1960. There were 71 fishing days when 140 hauls were made. The total quantity of mackerel landed was 971·11 m. tons. In December, with 53 hauls in 20 fishing days a maximum of 386·74 m. tons was landed while the lowest catch of 2·81 m. tons as a result of 9 hauls in 8 days was recorded in February. The average per *rampan* operation, the average per fishing day, catch per haul per piece and the catch per haul per man were the highest in October, though in the month-wise distribution of the total catch, it occupied only the fourth place. The quantity hauled per *rampan* varied from 54,550 kg. in November to a mere 20 kg. in January. The catch per haul per piece of *rampan* and the catch per haul per man for the

year showed a poorer figure than that of even 1956–57 (which was the worst year on record).

Studies during the year revealed that there was no mixing up of populations, nor was there any indication of different age groups appearing in the same shoal. The fishery was mostly composed of immature fish measuring 170–220 mm. though during the close of April and early during the commencement of the year's fishery it was composed of spent individuals. No segregation of the sexes was noticed amongst the shoals. Stray specimens of young mackerel measuring 100–30 mm. occurred frequently during April, May, June and August. The occurrence of these young mackerel in April in the inshore waters of Karwar was noticed for the first time. They were believed to be stragglers from the main shoal which remained outside the fishing zone. Length-frequency studies in April revealed the 220 mm. group as dominant. During the season as a whole, the 200–10 mm. group dominated as in 1957–58 whereas in 1958–59 it was the 210–20 mm. group that formed the majority. During 1959–60 growth could be traced from 180–90 mm. in October to 210–20 mm. in February while the growth from October 1958–April 1959 was from 190–220 mm.

Taken for the season as a whole, male and female specimens equalled in numbers. In the April samples, the females constituted 67·2%; the majority of the specimens above 220 mm. were in the spent condition (stage VII), indicating that spawning had taken place either in April or late March. In the samples obtained during the off-season the gonads showed a ripening condition (stages IV–V). That the period of spawning was during the off-season months was further corroborated by samples obtained in October and early November. There was, however, one female specimen in which the two lobes of the ovary exhibited different stages of maturity, the right lobe in stage V and the left lobe "running" (VI B). The fully transparent ova with usually one bit oil globule but sometimes with 3–4 oil "globulets" measured 0·85–0·94 mm. in diameter. The big oil globule measured 0·23 mm. in diameter. Another peculiarity observed in this particular specimen was that the contents of the left lobe could be completely emptied leaving behind a thin bag-like structure.

Study on the relationship between the total length, standard length and body weight was continued. In connexion with the racial investigation studies it was discovered that the Indian mackerel is characterised by six posterior finlets (both dorsal and anal). Another observation was that the total number of dorsal fin rays (including finlets) numbered 29 (and not 27). But these 29 rays were generally found only in the young fish. It was observed

that during growth, 1 or 2 (or rarely three) lepidotrichia of the first dorsal fin got shed, by the corresponding interspinous bones persisted. Instances where the last one or two rays of the second dorsal and anal fins getting modified as finlets were also noticed. Whatever these modifications were, the total number of (dorsal) interspinous bones remained constant as 29 while those of the anal were 18. Comparative studies with *Rastrelliger* species from other regions on the Indo-Pacific have been contemplated.

(*b*) *At Mangalore.*—The mackerel fishery was a complete failure in the area around Mangalore during this year. The total annual catch at Ullal amounted only to about 21·6 m. tons. Of this 5 m. tons were landed in April and May. There was no fishing during monsoon but the season started again in September. But the total catch in September and October at Ullal was only about 13 m. tons. After October, the fishery declined further. At other centres also, the fish catches were much below normal. At Ullal, *pattavala* and *kanthavala* accounted for about 90% of the total annual catch. About 90% of the *pattavala* catch was landed in September and October. Of the two nets, *pattavala* was the more important one, both in regard to total landings and catch per unit of effort.

From length-frequency studies it was seen that the catches of the April–September period were supported by the same age group which had contributed to the 1958–59 season (October 1958–March 1959). This age group disappeared from the fishery after September. From October onwards, the fishery was supported by a new age group. This was represented by a modal length of 190–94 mm. in October 1959, and 220–24 mm. in March 1960. The catches of both gill-nets and *rampan* showed the same pattern with regard to age composition, but during October 1959–March 1960, the monthly modal sizes of gill-net landings were 5–10 mm. higher than those of the latter.

Mackerel of advanced maturity (stages V–VI) occurred in the fishery from April–August 1959. From October–March 1960 the fish were mainly in stages I and II.

There was a fishery of a very minor magnitude in the Netravati estuary in May 1959 and from December 1959 to March 1960. From October 1959 to March 1960, the size frequency of fish in these catches had the same modal length as that of the marine catches, but in May 1959 the modal size was about 20 mm. higher. Catches landed by purse-seine in January at Mangalore also had the same modal length group as with indigenous gear.

The main items observed in the stomach contents were copepods, cladocera and larval bivalves among zooplankton and *Coscinodiscus* among phyto plankton.

(*c*) *At Kozhikode.*—The annual mackerel catch of 471·13 m. tons constituted 13·50% of the total landings of fish at Calicut. The seasonal catch was about one-third that of the 1958–59 season. The mackerel fishery in October and November was, however, better than the corresponding months of 1957–58.

In August and September the fishery was contributed by a smaller size-group with a modal size at 125 mm. in August and 165 mm. in September. In October the fishery was contributed by a larger size-group with the dominant size at 185 mm. The prevailing overall length of mackerel in November and December was 205 mm. and that in January–March 215 mm.

Larger mackerel, 210 mm. and upwards, were in advanced stages of maturity (stages IV, V, VI) during May–August. From October–April, mackerel were in stages I–III.

The studies on the food of mackerel was started by December. Stomach contents of fishes ranging from 204–31 mm. were analysed. The stomachs were full in most cases mainly by copepods. Phytoplanktonic forms made up a small portion of the food, composed chiefly of species of *Dinophysis*, *Coscinodiscus*, *Peridinium* and *Pleurosigma*. Large numbers of tintinnids were also seen. Among other food items were crustacean eggs and larvae, bivalve larvae, and cladocerans.

Specimens received from Andamans during this year were examined in connexion with racial studies. The vertebral column of these specimens resembles that of the local mackerel. The gill raker counts show great variation in different specimens, there being 18–24 (mostly 20–22) on the upper branch and 34–41 (mostly 36–38) on the lower branch of the first branchical arch.

(*d*) *At Ernakulam.*—Mackerel fishery at Cochin was of very moderate magnitude during the period under review. The country-crafts with *thangu vala* (boat-seine) and *aila vala* (gill-net) fished up to areas 7 fathoms deep and the purse-seine mostly in the 6–8 fathom area. During the close of the fishing season in April and May fish ranging in length between 200 and 230 mm. with the modal length 220 mm. were caught in moderate quantities. Fishing again started in October with the appearance, in significant quantities, of fish with modal lengths of 180 and 190 mm. and which increased to 210 mm. by March.

Fish in fairly advanced stages of maturity (up to stage IV) and spent conditions were noticed in April and May, of first quarter and March of the last quarter. No fish in ripe of running condition has been observed

in the catches at Cochin. Search for mackerel eggs in plankton collections off Cochin did not prove fruitful. The smallest mackerel observed at this centre (56 mm.) was collected in August from the 20-fathom area. Generally the females exceeded the males in number in the samples but a reversal of this pattern was noticed in February and March.

(*e*) *At Neendakara.*—Mackerel specimens beyond the IV stage of maturity have not been met with at any of the landing places here during the year. Fish with gonads in stage IV appeared in May and June. A sample of 6th May was interesting in that specimens of different size-groups (149–72 mm. and 221–49 mm.) were brought in by the same shore-seine haul. The smaller specimens belonged to stage I of maturity while the larger ones were in stage IV. The commercial fishery was supported by fish of stages I and II only. Studies on the food and feeding habits and otoliths were continued.

(*f*) *At Vizhingam.*—The mackerel fishery at Vizhingam was mainly based on the stock of juveniles and of the medium-sized fish. During the period under report, the fishery showed considerable improvement as compared with that of the previous year. The total landings were estimated at 66,223 kg. of which 8,897 kg., 51,012 kg., 5,152 kg. and 1,162 kg. were recorded during the first, second, third and fourth quarters respectively.

Shore-seines, boat-seines and drift nets were the main gear employed for mackerel fishing. Of these units the former two accounted for more than 90% of the total landings. Mackerel was also caught occasionally by hand-lines at Valiathura, Trivandrum.

The bulk of the commercial catches was supported by the juveniles and the medium-sized fish, while the adult fish contributed only to a small fraction of catch. During the first quarter two size-groups, 50–60 mm. and 90–140 mm., were of common occurrence in the landings; the adult fish of size range 200–50 mm. were recorded as stray specimens. But by the second quarter, the size classes 80–120 mm., 130–50 mm. and 160–90 mm. entered the fishery. Slightly bigger fish of size range 140–220 mm. with modal sizes at 180 mm. and 200 mm., were recorded during the third quarter. The size of the mackerel showed a progressive increase in the last quarter. The length composition of the fish during the quarter varied from 200–95 mm. Stray specimens of juveniles of the size class 45–70 mm. were also recorded at the end of the period.

The major portion of the commercial landings was constituted by the indeterminates and immature fish, while the adult fish, caught at different parts of the year as stray specimens, were in various stages of maturity. Thus

the fish caught during the first quarter were found to be in the maturity stages II, IV and V. Subsequently no adult fish was recorded in the commercial landings except at the close of the season. During this period all the fish measuring below 240 mm. were in stages I and II, while mackerel measuring above 260 mm. in length were in spent condition (stage VII).

The mackerel was feeding exclusively on planktonic organisms. The feeding intensity was observed to be uniform throughout the period. The preponderance of various types of the planktonic organisms found in the stomach varied from season to season. Thus during the first and the last quarters zooplanktonic forms like copepods, *Squilla* larvæ, prawn larvae, Pelecypod larvae, and *Acetes* sp. formed the important constituents, while during the second and third quarters the phytoplanktonic fraction constituted the major item of their food.

(*g*) *At Porto Novo.*—The total mackerel landed was 5·12 m. tons, the entire quantity being accounted for by a continuous and rather prolonged summer fishery. The usual August–September fishery at this centre was a failure. The bulk of the catches were constituted by spawners of 200–40 mm. size. But the possibility of actual spawners moving out of the intensely fished area was indicated.

3. *Prawns and Lobsters—(A) Prawns*

(*a*) *At Bombay.*—A comprehensive study of the inshore prawn fishery along the coast of Bombay between Dahanu and Sassoon Docks was initiated in September. Weekly observations were started on the *Dol* net catches at 4 centres, *viz.*, Dahanu, Arnala, Versova and Sassoon Docks but later observations at Dahanu had to be abandoned owing to certain practical difficulties. About 10 species of prawns and shrimps have a significant share in the fishery at all the centres. The different species and their average percentage (given within brackets) were *Acetes indicus* (26·2), *Metapenæus affinis* (16·5), *Palæmon* (*Leander*) *tenuipes* (13·8), *Hippolysmata ensirostris* (9·7), *Solenocera indicus* (9·6), *Parapenæopsis sculptilis* (8·3), *P. hardwickii* (5·0), *P. stylifera* (4·0), *Metapenæus brevicornis* (2·3) and *M. monoceros* (2·1). Besides these there were a few other species also which occurred erratically in some months, but whose contribution to the fishery was rather small when the entire region is taken into account. Few of the species mentioned were uniformly abundant in all the centres in any month. It might be of scientific interest to mention here that *Parapenæopsis hardwickii*, *Metapenæopsis novæguinea* (*stridulans*), *Atypopenæus compressines* and *Trachypenæus curvirostris* have not been recorded before from the West Coast.

Two other species, *Muyadiella pedunculata* and *Parapenæopsis acclivirostris* have not so far been recorded from Indian waters before.

Among the numerous species Penæid prawns, which are caught in good numbers in October and November, formed only about 47% of the total landings, whereas smaller species like *Palæmon* (*Leander*) *tenuipes*, *Acetes indicus* and *Hippolysmata ensirostris* accounted for as much as 50% of the total.

The months of October and November were noteworthy because of the intense breeding activity of most of these species. None of the penæids seem to spawn in inshore areas. Mature *M. monoceros* was observed only in October.

The prawn catches of the Government of India vessels consisted of *M. affinis*, *M. brevicornis*, *Parapenæopsis stylifera*, *P. sculptilis*, *M. monoceros*, *M. maxillipedo* and *Penæus indicus* in the order of their abundance. Except for the occasional capture of the juveniles of some species most of the prawns were adults. Although observations on the prawn catches of the Bull Trawlers of the New India Fisheries Limited had to be abandoned from October 1959, earlier observations showed that the catches were rather poor. They comprised *M. monoceros*, *M. affinis* and *P. indicus* in the order of their abundance. This was true up to the region of the Gulf of Cambay. North of it, in and around the Gulf of Cutch, *P. indicus* and *P. carinatus* appeared to be the dominant species.

(*b*) *At Mangalore.*—In the Mangalore area prawn fishery with indigenous gear was better during the year under report with its peak in August–October. *M. dobsoni* was the dominant species, others being *M. affinis*, *P. indicus* and *P. stylifera*. Good numbers of impregnated females were observed during August–November indicating the probability of their breeding during these months. The catches from the Netravati estuary were made up of juveniles of *M. dobsoni*, *M. monoceros* and *P. indicus*.

Mechanised vessels using other trawl landed fairly good catches from October 1959–March 1960, which might therefore be the best months for prawn fishery by this method. Composition of the species caught seemed to be almost the same as those of the indigenous gear. *P. indicus* and *P. penicillatus* were also present in insignificant numbers. Impregnated females of *M. dobsoni* in appreciable numbers were observed in these catches up to March and it seems probable that the breeding period of the species in this area might extend from October–March.

(*c*) *At Kozhikode.*—Routine collection of data from catches at Calicut and Quilandy and these mechanised vessels operating from Beypore were

continued as in previous years. The catches mainly consisted of *P. stylifera*, *M. affinis*, *M. dobsoni* and *P. indicus*. Observations on their biology have also been regularly made especially in regard to growth, maturation and breeding.

(*d*) *At Ernakulam*.—Studies on the prawn fishery at Alleppey, Chellanam and Narakkal, as part of the programme of population and recruitment studies, have been carried out during the year. On reviewing the fishery at Alleppey during the 4 years from 1956–57 to 1959–60 it became clear that the fishery has been steadily declining and that the year under report has seen the poorest landings in the 4 years. *M. dobsoni* continued to be the dominant species, especially during the peak of the fishery from May–September. Later there has been a fall in its numbers. During these months older prawns belonging to length groups of 96–100 mm. to 106–10 mm. were prominent. By November they became fewer and their place was taken by younger prawns measuring 61–65 mm. to 71–75 mm. *P. stylifera* was next in importance. Length-frequency studies have indicated that lower size-groups are recruited into the fishery some time after August and also after February. *M. affinis* occupied the third rank and was observed in maximum numbers in November and December. Its modal length group measured 71–85 mm. in February–March; but later, in November–December, groups measuring 111–40 mm. became more prominent.

The fishery at Chellanam and Narakkal was similar to that at Alleppey in regard to species and their fluctuations, both in number and size. But in respect of monthly landings those of the two southern centres were much less.

With a view to gather as much information as possible on the distribution of Penæid prawns off Cochin and in the neighbouring areas a close study of the prawn catches of two trawlers of the Government of India and two vessels belonging to the Indo-Norwegian Project has been started in the last quarter of the year. The data collected so far are insufficient to base any conclusions on them.

An investigation on the biology and fishery of *Palæmon carcinus* was initiated in September 1959 at two centres in the Vembanad lake area where this fishery is quite good. From the observations made before the end of the fishery in November it would seem that the catches mostly consisted of males between 240 and 300 mm. and females measuring 150 and 240 mm. From the number of berried females observed the period of active breeding of the species seems to be October–November. After the termination of

the fishery studies on their post-larvae and young ones have been continued in order to trace their distribution and growth.

Reports from industrialists had indicated that, contrary to the prevailing belief that there is hardly any prawn fishery south of Quilon, a fishery of some magnitude exists at certain places in the region of Kanyakumari District. The fishery starts in June along the coast extending from Cape Comorin to Kollengode, about 35 miles to the north and lasts up to about August although some prawns may be caught in later months. The nets used are those known locally as *Thattumadi* and *Vala valai* and they are operated comparatively close inshore, seldom beyond 2 miles in waters 2–7 fathoms deep. With the help of the Southern Fisheries Corporation, who were buying a good part of the catches for freezing in their Unit at Muttom, it was almost entirely of *Penæus indicus*. One noteworthy feature was that the young ones of this species were relatively few in the inshore catches compared to those at other places, the majority of them measured over 140 mm. in length in June, August and December 1959. Before the freezing companies appeared on the scene it is reported that the catches used to be shelled and dried for export to Ceylon from the Port of Tuticorin.

(*e*) *At Madras.*—*P. indicus*, *P. carinatus* and *M. dobsoni* composed the marine catches in the local fishery. The first of these species, ranging in length from 120–200 mm., formed almost the entire catch.

In addition to the studies on the local fishery the fairly rich fishery of the Pulicat Lake, about 45 miles north of Madras, was taken up in the second quarter of the year. Stake-net fishing is the most widely practised method in the Lake, and the operations are carried out at night in places 2–8 metres deep. The period January–March was the best for prawns this year. As in other estuarine environments the catches consisted almost entirely of young and immature prawns. *P. indicus* and *M. monoceros* were the important species making up the bulk of the catches while *P. carinatus* was also caught but in small numbers.

(*B*) *Spiny Lobsters*—Panulirus *spp.*

The fishery of 1958–59 season which had begun to decline in March 1959 came to a close by the end of April. It revived by about the middle of December 1959. The catches during this season had gone down strikingly, but it is difficult to furnish a satisfactory explanation for such a sharp decline. The estimated catch (numbers caught) for each month in the current and last seasons furnished in the table below gear-wise would show the extent of the fall clearly. The decline was noticeable not in numbers

alone but also in size. Lobsters of larger size (over 200 mm.) were proportionately much less, especially in the first two months of the current season and among this size males were less than in the last season. Females with eggs were also much less in numbers during the current season, except in December.

		Colachel					Muttom				
		Dec.	Jan.	Feb.	Mar.	Apr.	Dec.	Jan.	Feb.	Mar.	Apr.
Trap	..	16398	18228	9196	3255	1114	7359	14672	6920	2752	328
	..	6616	4046	1919	745	1114	4866	4608	3244	926	926
A. Hook	..	Nil	Nil	60	70	Nil	46286	21989	2222	57	267
	..	Nil	1370	V. few	Nil	Nil	12852	5212	2342	212	212
G. Net	..	3560	1064	50	Nil	Nil	Nil	Nil	58	Nil	Nil
	..	338	120	Nil	Nil	Nil	Nil	22	Nil	Nil	Nil

(The first set of figures under each gear represent the numbers for the 1958–59 season while the second series are for 1959–60.)

4. *The Malabar Sole*—Cynoglossus semifasciatus

About 241·5 m. tons of the Malabar sole, *Cynoglossus semifasciatus*, were landed at Kozhikode (Vellayil) during the year. Of this quantity as much as 164·5 m. tons were landed in October and 47·6 m. tons in November. In September which is normally the month of peak catches of this fish, only 1·2 m. tons were landed. There was practically no fishery in the area for soles during July and August and most of September. Small quantities of this fish occurred in all the other months, ranging from 0·7 m. tons in February 1960 to 10·4 m. tons in June 1959. Outside the monsoon season the monthly total catch was less than 3 m. tons in five months of the year.

Departmental collections with the boat-seine and gill-net were also continued throughout the year and the samples taken with the boat-seine were used for length-frequency studies. The dominant size was in the 90–99 mm. group; from April–June. Juveniles occurred in all these three months though there was a relative reduction in their numbers through May–June. A single juvenile in the 50–59 mm. group was encountered in September. In October, the smallest specimens caught were in the 70–79 mm. group; these and the single juvenile seen in September perhaps belonged to

the previous season's late spawning. Smaller juveniles occurred regularly from November onwards, with a dominance in December. These represent a new brood entering the fishery. An interesting point about the length-frequency distribution during the months of April-June 1959 and January–March 1960 was the occurrence of the mode of the dominant age-class in the same size-group, namely, 90–99 mm.

Occasional samples were examined for scale rings and the findings fell in line with the age-classes as seen from the length-frequency distributions.

By October all the females were in an advanced stage of maturity as expected. In November, out of 78 specimens of all sizes examined, 63 were in stage V or above. In December, out of 74 females of all sizes examined, 61 were in stage V or above. Juveniles in stage I of maturity and also indeterminates occurred in good numbers from December onwards but ripe and recovering-spent stages continued to occur in the older age-class throughout the last quarter. Most of the older individuals of the new brood had reached stage III of maturity by March when there were also a few occasional specimens in still higher stages.

Plankton collections have been examined for further study of the eggs and larvae of this species and the work is being continued.

5. *Half-beaks*—Hemirhamphus *spp.*

There were good landings of *Hemirhamphus* spp. and *Hyporhamphus* spp. in the Mandapam area. Analysis of four morphometric and four meristic characters of *Hyporhamphus georgii* by the technique of Analysis of Covariance and Analysis of Variance respectively did not reveal between area differences.

The food of *Hyporhamphus georgii* at the different stages of maturity was different, partially due to their selective nature in food habits and partially also due to the different pattern of distribution of the spawners and the spent fish. The adults of *Hemirhamphus far* and *Hyporhamphus guoyi* feed exclusively on the sea grass, *Cymodocea.*

The present study has confined the single spawning of both *Hyporhamphus georgii* and *Hemirhamphus marginatus* by the investigations on the relation between ova diameter frequencies and the seasonal variations of the male and female maturity. The fecundity and sex-ratio of these two species have been investigated in detail.

6. *Seer fish*—Scomberomorus guttatus

The species constituted 3·7%, 6·8%, 57·2% of the total estimated fish landings at Lawsons Bay in March, April and May respectively. The very

high percentage composition in the month of May far exceeded any previous record and the estimated total catch of the species was more than double the peak catches during the past two years. Teleosts formed the bulk of the food of which species *Anchoviella*, *Sardinella*, and *Thrissocles* were the important items besides which crustaceans were also observed mainly represented by *Squilla*. Females were of a higher percentage in the samples examined than males. Majority of the specimens observed in March were in an advanced state of maturity while immature females were dominant in April and May. Length measurements showed that three modes were present in March namely 380–400 mm., 440–60 mm. and 500–20 mm. and from April–June modes at 360–80 mm. and 440–60 mm. remained constant. Morphometric measurements and meristic counts were made with a view to finding out racial differences.

7. *Mullets*—Mugil *spp.*

Detailed biological studies on the two species mullets, *viz.*, *Mugil cephalus* and *Liza macrolepis* from the Pullamadam lagoon (near Palk Bay) were continued with special reference to their growth rate. Preliminary observations made on the various aspects are detailed below. *Mugil cephalus*—The stomach contents of juveniles showed Foraminifera forming the major item in the food taken along with decayed organic matter and algæ. The 'breaks' observed in the circuli on the scale of fish collected between December 1958 and January 1959 did not occur in any month during the year. Therefore, it is doubtful whether these 'breaks' could be taken as annuli. During December–March immature gonads (stages I–II) were seen in fish beyond 200 mm. (length to caudal fork—L.C.F.). Nematode parasites belonging to the genus *Paranisakis* were found in the body.

Two distinct size-groups, 97–139 mm., and 205–301 mm. were caught in the lagoon in January. But the latter size-group no longer occurred in the catches from March. It is of interest to note that when these large-sized mullets (about 205–301 mm.) scarcely occurred in the lagoon catches on 3–3–1960, fish of about 321–407 mm. were caught on 5–3–1960 in the shallow areas of the Gulf of Mannar around the Manauli island, by the same net. These fish were in stage II of maturity. Continued observations on this differential distribution of the size-groups might throw some light on their spawning behaviour.

Liza macrolepis.—The food of juveniles is basically the same as that of *Mugil cephalus*. *Pleurosigma*, *Navicula* and *Nitzschia* formed the major items in the food of fry. Mature and spent fish obtained in the catches from the sea had mainly Copepods and Diatoms in their stomachs. Although

mature individuals were encountered in the lagoon and Palk Bay catches from June–January, the peak period for them was from June–September, when they were caught in the sea by *Vidu valai* and cast nets. They ranged in size from 186–313 mm. Younger size-groups, about 85 mm. were caught in the lagoon almost throughout the year, the largest size caught being 232 mm. Detailed studies on the food, maturity and growth rate are under progress. The weekly departmental plankton collections from Palk Bay and Gulf of Mannar during June–August were examined for the occurrence of the larval stages but with little success.

8. *Tunnies*—Katsuwonus pelamis

Since the earlier g neral survey of the fishing industry of Minicoy Island in the Laccadive Archipelago, with special reference to Tuna fishery, the study of the biology of tunnies was actively being pursued. Although thunnids occur along the Indian Coast their larval forms are not known. It has been possible to collect and identify the early larvæ of *Katsuwonus pelamis* and *Neothunnus macropterus* from the Laccadive Sea.

Knowledge of the kind of organisms on which skipjack (*Katsuwonus pelamis*) feeds and the relative abundance of different organisms are of importance to our understanding of the aggregations and behaviour of skipjack in the Laccadive Sea. The major items of food may be divided into (i) crustaceans, (ii) cephalopods and (iii) juvenile and larval fishes. Among the crustaceans stomatopod larvæ, mysids and megalopæ predominate. Fishes consist of juvenile of Balistidæ, Ostraciontidæ, pipe fishes, etc. Organisms of various sizes are found. The e does not seem to be any sclective feeding. Instead they appear to snap any organism that "wriggles" or swims in the open sea. Most of the stomachs were either empty or with only traces of food materials excluding bait fishes. Therefore the hungry fishes migrating for food towards the coral reefs and lagoons which sustain a comparatively rich fauna appear to contribute to the fishery.

Mature gonads are found mostly throughout the year. But the occurrence of ripe gonads during certain months along with spent gonads indicates that period as the spawning per od. Gonads in the most mature stages but not yet shed are found in November and December. But spent ones are not found until April. Therefore the active spawning period is between these periods. The continued occurrence of spent ones up to August suggests that it is a prolonged one. The studies on ova diameter reveal two spawning periods within the season by the presence of two peaks. The fecundity in relation to fish length and weight was also completed. The unequal sex ratio with males predominant during the spawning period and subseqeuntly

the females when the spent fishes are found in catches to suggest that the spawning females most probably avoid the bait.

9. *Molluscs*

The data collected while collaborating with the scientific staff of the Madras State fisheries and the F.A.O. Underwater Expert in the survey of the Pearl Oyster beds off Tuticorin were analysed. The survey of a few paars such as the Tholayiram paar, the Pernando paar and the Devi paar was carried out in a detailed manner. The Tholayiram paar is the biggest with an area of about 9·84 sq. kilometres and a total population of about 9.84.00.000 oysters. The analysis of the size-frequency distribution of oysters of the Tholayiram paar clearly indicates that they belong to the same brood. Since they have not attained the minimum fishable size, it is felt that the oysters should be allowed to grow for one and half years or more before they are fished. The survey also indicates that the Pernando paar has an area of about 0·20 sq. kilometre with a population of less than 2.00.000 oysters and the Devi paars about 0·13 sq. kilometre with a population of less than 50.000 oysters. The survey carried out on the southern paars did not reveal the presence of any live oysters at present in any of these paars. Only dead oyster shells were found in most of the places. Regular weekly collections of plankton and water samples were made from the Tholayiram paar area from December 1959 onwards and a detailed analysis of the water samples for various nutrient salts, salinity, dissolved oxygen, etc., is in progress. The study on the seasonal gonadial variation of the adult pearl oysters was started during the month of March 1960.

B. *Offshore Fisheries Investigations*

(*a*) *At Bombay: Commercial trawling operations.*—The two pairs of Bull trawlers of the New India Fisheries Limited operated from December 1959 onwards. One pair of these vessels did not operate from the post-monsoon period to December 1959. Hence the total catch was reduced from 36,15,648 kg. during 1958 to 27,25,478 kg. during the year 1959. Among the commercially important species being studied at Bombay, Eels constituted 14·44%, *Karkara* 10·27%, *Ghol* 6·51%, *Dara* 3·68%, *Koth* 2·01%. The catches from January–April were high due to concentration of trawling in the grounds off North Kutch, Dwaraka and Porbunder of which the North Kutch area had shown rich grounds of *Karkara*. During the monsoons the operations were confined to south of Veraval in the Cambay and Bombay areas and eels formed the major fishery during the period.

A total of 2,98,919 kg. of fish were landed by the Government vessels. 50·7% of these landings composed of *dhoma* (mixture of small Sciænids like *Johnius* sp. and *Otolithus* sp.). The others, in order of abundance, were Elasmobranchs 20% (of which Sharks formed 20%, Skates 18% and Rays 62%); Prawns 9·7% *Ghol* 5%, Cat fishes 4·6%, Clupeoids 2·7%, *Karkara* 1·2%, *Koth* 0·7% and others 5·1%. The peak periods of abundance were from April-May and October–February. A salient feature of the Otter trawling operations was the consistent good catches of *dhoma*. A study of the composition of the species constituting *dhoma* fishery, their abundance, distribution and fluctuations will be of great value to the development of Fish Meal Industry proposed to be started at Sassoon Docks from the ensuing fishing season. At present the operations of the Government trawlers were confined to the Bombay region where the bulk of *dhoma* was landed. The few voyages made in other areas along the Konkan and Gujarat coasts also brought large quantities of *dhoma*. These fish have been found abundantly around the 15–20-fathom areas.

Three vessels of the Government of India, M.L. *Sagarkanti*, M.L. *Meera* and M.F.V. *Jheenga* operated from Veraval. The first one operated the gill-n ts and the latter two vessels operated the trawl net. These vessels together landed 1,11,633·49 kg. of fish during the year. M. L. *Meera* operated for the maximum number of days (130) and landed the maximum quantity of fish (64,820·69 kg.). M.L. *Sagarkanti* operated for 87 days and landed 13,472·45 kg. of fish. M.F.V. *Jheenga* operated for 43 days and landed 33,340·35 kg. of fish. This vessel had the maximum catch per hour during the year followed by M.L. *Meera* and M.L. *Sagarkanti*. The operations at Veraval were closed down in the last w e'k of February 1960.

Fishery and Biology of Important Species. (i) *Dara* (Polydactylus indicus).—A study of the fishery of *dara*, exploited in offshore areas by commercial trawlers since 1956–57, showed that they were mainly concentrated in 1,200 sq. miles of fishing grounds located off Luchington Shoals at the entrance of the Gulf of Kutch, and off Dwaraka (68° 30′–69° 00′ E. and 22° 30′–23° 00′ N.). The period off occurrence always extended from November–March of the following year as seen from the systematic trawling operations conducted from 1956–59. The average catch of *dara* per hour of trawling in 1957 was 129·5 kg. which declined to 76·6 kg. in 1958 and improved to 97·9 kg. in 1959. At the peak periods of December–February the catch per hour varied from 178·8–294·1 kg. in 1957, 52·8–301·9 kg. in 1958 and 140·1–314·2 kg. in 1959. During 1960, however, these areas were not regularly visited since the discovery of rich *Karkara* grounds in

regions north and north-west of these areas around the 20-fathom line and hence poor catches of *dara* were recorded in the catches in 1959–60.

Length-frequency studies showed three distinct modes at 400, 550 and 650 mm. during January–March with an additional mode at 750 mm. in February. This pattern was found in the earlier and later months of the previous year also. Length weight relationship showed that at 350 mm. the fish weigh 1 lb. (*ca.* 500 kg.) increasing at the rate of 300 gm. per cm. up to 600 mm., 150 gm. per cm. up to 720 mm., 500 gm. up to 1,120 mm. and 750 gm. up to 1,300 mm., to attain 60 lb. (27·2 kg.) in weight.

Most of the fish between 200 and 500 mm. were juvenile, 510–750 mm. immature and those above 800 mature. Spawners were recorded during May–June in the Gulf of Kutch. Further studies are necessary for understanding the nature of spawning and maturity. The adult and large-sized fish over 500 mm. feed mainly on smaller fish like species of *Johnius*, *Otolithus*, *Polynemus*, *Coilia* and *Cynoglossus*. Crustaceans like prawns, crab and *Squilla* were also found in good numbers in the stomach of smaller fish. Juveniles of less than 500 mm. are mainly predators of shrimps and crabs.

(ii) *Ghol*—(Pseudosciæna diacanthus).—A slight increase of 2,510 kg. was observed in the *ghol* landings of the Bull trawlers over last year (1958). The annual catch of *ghol* formed 6·51% of the total landings of the trawlers and occupied fifth rank in the order of abundance, while in 1958 it formed 4·38% of the total catch, occupying eighth rank. The fishery has been steady since 1957 and the peak landings for the year were observed in February, March and April.

From a study of the fishery of juvenile *ghol* at Versova, it would seem that specimens of 30–100 mm. observed in September are the products of spawning in July, August and these grew to a size of 200–50 mm. in about six months. Analysis of length-frequency data of trawler landings showed three to four modes in certain months while only two or even one in other months were recorded. The intensity of feeding in juveniles was observed to be more during September–December when prawns formed nearly 70–80% of the diet. In December, the food consisted mostly of fish which formed 47% of the gut contents and prawns diminished in proportion. Adult fish were found at stage IV of maturity and over from April–June. Spent fish were recorded from August and by October almost all the adults were found in the spent or recovering stages which continued up to March. The peak spawning period extended from September–November indicating protracted spawning. Ova diameter studies indicate the presence of only one spawning in the fish during the year. The study of scales showed

the fishes of 300–450 mm. had one growth check, 550–650 mm. 2 checks, 700–800 mm. 3 checks, 850–950 mm. 4 checks and 900–1,000 mm. 5 checks. Six rings were found in specimens of 1,000–1,100 mm. group. These growth checks coincided with the length-frequency modes up to four or five rings.

(iii) *Koth* (Otolithoides brunneus).—The major part of the *Koth* catches was made by Bull-trawlers of the New India Fisheries which amounted to 56,198 kg. or 2·06% of the total catch during 1959. Adults were completely absent in these catches. The lengths ranged from 270–1,025 mm. when inshore landings were also taken into account. Length-frequency polygons indicate that 0-year fish were represented around 175 mm., 1-year fish at 396 mm., 2-year fish at 595 mm. and 3-year fish at 805 mm.

Examination of gut contents showed that the *Acetes indicus* formed the dominant item among prawns and *Coilia dussumieri* and *Bregmaceros maclellandi* among fishes. The study of intensity of feeding showed that there were two distinct periods, one of high feeding activity during March–June and the other of low intensity from December–February.

Few mature fish were landed in offshore catches. Ova diameter studies of gonads collected during 1958–59 indicate the presence of one spawning in the year and that the ova are shed at one time.

Scale studies indicate that at 418 mm. the first ring is formed. Twelve rings were present in the scales of fish of 1,490 mm. long. Low-feeding intensity during November–February every year seems to be responsible for the formation of these rings. In the otoliths, however, the third ring corresponded to the first ring on the scale, the fifth to the second and the sixth to the third ring.

(iv) *Karkara* (Pomadasys hasta).—*Karkara* constituted 10·27% of the landings of the commercial trawlers for this year, whereas in 1958–59 they amounted to 5·4% only. It was noticed that the trawlers started operating in new grounds off North Kutch. The catch per hour in these areas ranged from 221·33–397·92 kg. per hour.

Age and growth studies with reference to otoliths showed the presence of clear growth checks of one ring in fish of 130–240 mm. length, two rings in 250–360 mm. These growth checks coincide with the length-frequency modes. Detailed studies are being carried out to establish the age of these fishes.

Analysis of stomach contents showed a predominant crustacean diet composed of *Squilla*, prawns and crabs. Fish also formed an important

item of food. Occasionally molluscs, *Echiurus* and polychætes were also found.

The study of maturity indicated the presence of mature fish from April–July and spent fish from August–October. Only one spawning in a year is indicated in the ova diameter studies.

(v) *Wam* (Murænesox talabonoides).—*M. talabonoides* constituted 14·44% of the total landings of the trawlers and occupied the first place in order of abundance in the commercial trawler landings. Total lengths of 144 specimens of *M. talabonoides* ranged from 260–1,965 mm. Specimens examined for food contents revealed the presence of teleostean fish, namely *Synagris japonicus*, *Platycephalus indicus* young eels, prawns and crabs. A few ovaries of *M. talabonoides* were studied to understand the maturation in the fish. Ova diameter studies point to the presence of only one spawning in a year. Otoliths examined show clear growth checks. Further data are being collected to correlate the checks with the length of the fish along with the other biological aspects, to understand age and growth. The skeletal study revealed the phenomenon of hyperosteosis in various skeletal parts. Teratosis of the caudal region was found to be common among both the species, the cause and nature of this mutilation is yet to be determined.

(vi) *Bombil* (Harpodon nehereus).—Length-frequency studies of fish collected at Versova during April–May 1959 showed one mode at 95 mm. Fishing was suspended from June–September. During October–December more than 50% of commercial catches consisted of juvenile fish below 200 mm. total length.

Maturity studies showed that the percentage of males was slightly higher during March–April (34%) while in May it was (25%). Among the females the percentage of mature fish between stages V and VI was highest in March 1959. Similarly spent fishes were recorded in high percentages in May 1959. The ovaries of all specimens examined during September were in stages I and II of maturity. During the last week of October fishes of advanced stage V of maturity were noticed. In November, however, 25% of the catch were found at this stage.

The study of stomach contents showed that *Harpodon* fed mostly on smaller fishes. This diet, in the order of abundance, consisted of *Bregmaceros maclellandi*, *Polynemus heptadactylus*, *Coilia dussumieri*, *Harpodon nehereus* and *Otolithus* sp. while in May this consisted of *Acetes* sp., *Leander tenuipes* and *Solenocera* sp. The feeding activity appeared to be considerably lower during September and gradually increased during October–November.

Raciation studies of *Harpodon* collected from Jaffrabad, Versova, Janjira-Murud and Masulipatam based on eleven morphometric characters indicate significant differences among seven characters at 1% level. This showed that populations of the different centres did not come from a single homogen ous stock. The catches of Versova and Janjira-Murud appeared to come from the same or closely related stocks. The Jaffrabad catches seem to originate from another independent stock.

(*b*) *At Ernakulam.*—From April–June 1959 the cutters PRATAP and ASHOK of the Government of India Offshore Fishing Station continued their bull-trawling activities in area 108 lying off Cochin and landed 1,21,651 kg. of fish with an average of 1,237 kg. per hour of trawling. During the monsoon break which followed, these vessels were reconverted into otter-trawlers and M.T. Ashok was removed to the newly opened offshore fishing unit at Vizagapatnam and M. T. Pratap was left at Cochin to continue the work independently with the help of an 84′ otter-trawl.

During the period from September–February Pratap landed a total quantity of 1,04,358 kg. of fish spending 626·74 hours in actual trawling. The average yield worked out to 167 kg. per hour, which is very much lower than the seasonal averages realised by bull-trawling in the previous years from the same grounds and the composition of the catch also did not show significant changes. 'Miscellaneous small fishes' formed the major portion of the catches which contained larger proportion of *Nemipterus japonicus* and *Lactarius lactarius*. Prawns were scarce.

1957–58 season seems to have yielded the best results as far as the total catches were concerned. Examination of the data shows that there is a consistent decline in the rate of yield of fish in February and June. The decrease noted in June is borne out by the results of the other vessel also but that noted in February is found in the matter of bull-trawling only. The reason for this consistent decline in the catch rate in June cannot be attributed to lesser amount of effort in that month, but it has to be considered as a regular phenomenon, possibly bought out by environmental factors.

During the four seasons in which the cutters were operating from Cochin the exploratory fishing was carried out in 15 areas distributed from Calicut to Cape Comorin in depths ranging from 13–50 metres; but with the exception of 4 areas, *viz.*, 106 A, 108, 110 and 111, lying off Cochin and Alleppey all the other areas have been visited only occasionally. Of the total fishing effort put in by these vessels as much as 85% was spent in those areas.

In the months of February and March 1960 two voyages were undertaken by Pratap to Wadge Bank areas, from where altogether 19 hauls were

Table showing the average catch-per-unit-of-effort (kg. per hour) of trawling during the four seasons

	1956–57	1957–58	1958–59	1959–60*
September	..	..	..	60
October	..	..	..	252
November	..	672	..	168
December	..	1215	..	189
January	..	1203	611	135
February	..	859	536	191
March	406	1036	1498	..
April	454	1462	1367	..
May	450	1364	1206	..
June	218	520	564	..
Yearly Average ..	424	1038	954	167

* Otter trawling.

taken. The catches were not particularly encouraging although very rich in variety. It consisted mostly of species of *Chætodon*, *Lethrinus*, *Holocentrus*, *Lutjanus*, etc.

In January and February two Tuna-fishing voyages were undertaken by the research vessel Kalava of the Indo-Norwegian Foundation and the purse-seiner Bangda of the Deep Sea Fishing Station, Bombay. During the first voyage 7 tunas were caught from waters around the Laccadive Islands and 2 from near the main land in Kalava's trolling line. Tuna shoals were seen in many places but attempts with purse-seine were not successful. Second voyage was undertaken along the 25–30-fathom line off the coast from Cochin to Cape Comorin. During this trip 6 tunas were caught in trolling line and one in the drift net but none was caught in the purse-seine which was operated twice. *Euthynnus affinis*, *Neothunnus macropterus* and *Katsuwonus pelamis* were represented in the catch.

Shrimp trawling: (i) *By boats of the Offshore Fishing Station, Cochin.*— The small fishing vessels DURGA, TARPON and SAMUDRA of the Offshore Fishing Station, Cochin, continued to carry out shrimp trawling operations during the period under report. With the exception of a few hauls taken from areas 111 and 110 and a voyage by DURGA to Mangalore where she did Bull-trawling, all the other operations were carried out within 25 miles from Cochin fairway light buoy in areas 108 and 106 A, in depths ranging from 5–55 m. The total landings of these three vessels from April 1959–February 1960 amounted to 3,33,349 kg. over a trawling time of 1,598·6 hours; the average catch being 208·52 kg. per hour. The monthly catch rates varied from 35 kg. per hour in June to 283 kg. per hour in October. The catch returns were found to be distinctly higher in the post-monsoon months than in the pre-monsoon months.

The total catch of 3,33,349 kg. at the rate of 208·52 kg. per hour realised by these boats during the current season is more than double the catch realised by the same boats in the previous season; the catch of the previous season being 1,43,222 kg. at the rate of 104·54 kg. per trawling hour.

'Miscellaneous small fishes' constituted 48·8% of the catches while the other categories were Prawns (19·2%), *Lactarius lactarius* (8·5)% and sharks and rays (7·6%). From October–February there was a progressive increase in the landings of 'miscellaneous small fishes' raising from 13,508 kg. in October to 53,047 kg. in February. In September and October when the trawlers operated in deeper waters beyond 37 metres depth *Nemipterus japonicus* formed the dominant catch and constituted more than 80% of the total catch. While prawn catches were poor in the earlier part of the season there was a significant rise in their occurrence in January and February when they formed 15·9% and 19% respectively of the total landings in those months. From November–February *Lactarius lactarius* formed one of the important category. Its percentage in the total catch varied from 6·3–13·3% in certain months.

(ii) *By boats of the Indo-Norwegian Foundation.*—Although some of the medium boats of the Indo-Norwegian Foundation commenced fishing in late September the full fleet comprising of the boats M_2, M_3, M_4 and Flying fish started shrimp-trawling operations only from October. In early December ASHTAMUDI joined the operations and in the middle of December M_1, the boat hitherto engaged in Purse-seining, joined the trawling fleet. Since December all these vessels except FLYING FISH were working off Cochin. Fishing was mainly carried out at 5–25 fathoms depth in area 108.

Details of catch

Months	Total catch (kg.)	Catch/hour (kg.)
September 1959 ..	2,243	57·5
October ..	25,627	262·2
November ..	17,172	111·2
December ..	39,573	111·2
January 1960 ..	62,280	140·8
February ..	76,509	177·9
TOTAL ..	2,23,404	AVERAGE .. 151·37

In September the fishing operations were poor. The best catch return of 262 kg. per hour was realised in October but the rate of yield came down to less than half in the next month and remained steady in that condition till the end of December. From January onwards the catch rate was seen to increase indicating the same trend observed in the catches of the small vessels of the Offshore Fishing Station.

In September, October and even in early November, when the post-monsoon fishery was not established in the shallower regions, these boats were concentrating in the deeper regions (20–25 fathoms) to capture the *Kilimeen* (*Nemipterus japonicus*) which were then plentiful in those regions and formed 85% of the total catches of these months. November onwards, with the boats shifting their operations to the shallower grounds, 'miscellaneous small fishes' comprising *Lactarius lactarius*, Sciænids, Carangids, Upeneids, Ribbon-fish, Cat-fish, etc., began to dominate in the catches. Prawns appeared in small quantities in November and constituted 22% in December, 32% in January and 49·6% in February.

Purse-seining.—The boat M_1 started experimental Purse-seining off Cochin in area 100 from late September for catching mainly sardine and mackerel. In September no shoals were encountered. In October a total of 4,295 kg. of fish were landed of which mackerel and sardine respectively constituted 56·5% and 42·6%. In November lesser mackerel and sardine shoals were met with and major portion of the 7,524 kg. of fish netted consisted of elasmobranchs and *Sardinella fimbriata*. In December and in the first week of January a total quantity of 44,569 kg. of fish was landed of

which 43,179 kg. was oil sardine. Mackerel was very few. After the first week of January the boat M_1 joined the trawling fleet.

Biology of Nemipterus japonicus.—Detailed studies on the fishery biology of *Nemipterus japonicus*, a percoid fish occurring abundantly in the trawl catches were taken up from the beginning of this season. In September, this fish constituted more than 80% of the total catches of the small vessels operating in areas 106 A and 108 in depths over 37 m. In the subsequent months the fish was scarce in the catches since the trawlers shifted their operations to the shallower waters of depth 13–27 m. But from February onwards it started to appear in the shallow waters also and were caught in large quantities. While the modal size of this fish fluctuated between 120-30 mm. in September–December it advanced to 140 mm. in January–March. In the latter period specimens of 80–100 mm. were also encountered which indicated recruitment of the smaller size-groups. The species begins to attain maturity from September and by October–November majority of the fishes between 100 and 150 mm. were in stage IV and above. The number of mature specimens declined in December and from January onwards immature specimens of stage II and below dominated in the catches. Prawns, polychætes and fish were the common food elements met with in the stomachs.

(*c*) *At Tuticorin.*—During the period under report frequent trips were undertaken on board the vessels of the Offshore Fishing Station, Tuticorin, and the fishing data collected were analysed and compiled. Six vessels were operating for varying period of the time during the year. The area of fishing was within a radius of 12 miles from Tuticorin. Bottom-set gill-nets, driftnets, long-lines, revolving chain hooks and trolling lines were used. The data are summarised in the following table:

Name of vessel		Number of sets	Total catch (kg.)	Catch/set or/100 hooks (kg.)	Sharks and rays (%)	*Chroinemus* (%)	Perches (%)	*Caranx* (%)
Sardinella	Bottom-	73	7131	98·40	30·6	18·2	20·9	7·2
Sagar Sundari	set	36	48·4	133·50	26·8	33·1	21·5	6·8
Sagar Kumari	gill-	30	1022	34·10	48·0	..	12·5	15·5
Meenakshi ..	nets	76	5405	71·70	19·0	17·0	10·6	39·7
Sagar Kumari ..	Drift-	18	162	9·00	57·7	..	..	..
Sagar Sundari ..	nets	10	131	13·10	36·1	..	..	..
Sagar Sundari ..	Long-	33	200	2·27	..	..	50·0	..
Meenalochani ..	lines	29	238	2·73	..	..	58·1	..
Gudjon ..	R.C. Hooks	11	1215	157·10	100	..	..	..

It was seen that bottom-set gill-nets were the most successful. Trawling could be done only off Pinnakayal as the ground elsewhere is unsuitable for the purpose. SAGAR KUMARI brought a total catch of 3,113 kg. over 58 hours of trawling with a catch per hour of 53·61 kg. Prawns constituted 26·14% of this catch. Drift-nets and long-lines were ineffective while revolving chain hooks were promising. Trolling was unsuccessful. In the bottom-set gill-nets sharks, rays, *Chorinemus*, perches, and *Caranx* were the important fishes caught. The last three were taken in greater quantities during May–June and in September.

(*d*) *At Waltair.*—Work was undertaken in October 1959 in collaboration with Mr. Naumov, F.A.O. Fisheries Expert and in pursuance of the programme the research staff of the Unit availed of the voyages of the fishing trawlers of the Deep Sea Station, Government of India. Six trawling trips of M.V. ASHOK and four of M.V. SEA HORSE were utilised for scientific observations and collection of fish specimens up to end of March 1960. The first trip in the month of November on board M.V. SEA HORSE was of a more exploratory nature and it was observed that the catch off Visakhapatnam was predominantly *Anchoviella* spp. The vessel was stationed at Lion's Rump for fishing in the area around the mouth of Mahanadi. Trawling was conducted at seven areas and the Scientific Officers who participated in trawling made notes of common fish occurring in these grounds, other important fishing data, besides temperature recording and collecting specimens for further laboratory examination.

The area of operation for M.V. ASHOK was mainly off Orissa Coast in depths ranging from 18–24 fathoms. In addition to making collection of specimens, the Officers who participated in these cruises recorded the fishing data, nature of bottom, temperature, etc.

The work of analysis of the fish collections is being continued in the laboratory with special stress on the breeding and feeding habits of the major and more important species occurring in these waters.

(*e*) *At Calcutta.*—A total number of twenty-six voyages were performed by the West Bengal Fisheries Trawlers, Kalyani I–V during the period under report. The voyage of Kalyani I was a complete failure and unproductive as the vessel met with rough weather and heavy damage. Table on next page gives details of the fish catch of the different vessels.

Information such as the general catch area of operation, depth range were gathered from the Master after the vessel's arrival, at the fish landing centre (shore base station).

Name of vessel	Number of voyages	Fish catch (in kg.) 'A' class	'B' class	'C' class	Total catch in kg.
Kalyani II ..	6	531·00	83515·87	254·46	84301·33
Kalyani III ..	7	4358·31	49991·45	1584·16	56933·92
Kalyani IV ..	7	893·39	27656·45	1926·31	30476·15
Kalyani V ..	5	1436·00	61757·98	2813·92	66007·90

Periodical voyages were made in Kalyani III and V (which are the only two vessels in which lodging facilities are available) by the scientific staff of this Unit in order to collect detailed data on the total catch per haul, catch composition, length measurements of important groups of fishes, etc., of the different offshore fishing areas. It is obvious that Black Pagoda is the most productive fishing ground. It is also of interest to note that each of these areas is dominated by different groups of fishes. When the catch composition of those different fishing regions is analysed it is seen that *Sciæna* spp. and glass-fish (*Kurtus indicus*) occur in large quantities in Sand Heads, off Mahanadi, Devi and Prachi rivers. Fourteen species of Sciænids were obtained of which the commonest forms were *Sciæna glauca*, *S. carutta* and *S. aneus*. The other sciænids are identified as *Sciæna diacanthus*, *S. axillaris*, *S. bleekeri*, *S. semiluctosu*, *S. coibor*, *Sciænoides brunneus*, *S. microdon*, *Otolithus ruber*, *O. argenteus*, *Umbrina russelii* and *Umbrina macropterus*. Pomfrets and other small perches formed the major catch of Black Pagoda. Though the three varieties of Pomfrets are available the commonest species is *Pampus argenteus*. The major catches in False Bay are clupeids; the common forms are *Pellona indica*, *P. elongata*, *Engraulis telara* and *Raconda russelliana*. 'Swatch of no grounds' is noted for quality fishes such as species of *Lutjanus*, *Parastromateus*, and *Pomadasys*.

There is some evidence from the data so far collected that the fish production is more during the winter season; December and January were the most productive periods when 1,39,119·10 kg. were obtained which formed more than half the total landings for the year. A gradual decrease in the catch was noted after January right through to April. No fishing activities were undertaken by the West Bengal Fisheries Trawlers during the monsoon periods May–July. When expressed in terms of percentage out of the total catch "A class" constituted 3·00%, while "B class" 93·30% and "C class" 3·70%.

Sciænids formed the most important catch constituting 63% of the total; a peak period in the abundance of Sciænids fishery was noted in the month of January. It was also noted that there is a remarkable increase in the fishery of clupeoids in the month of January con tituting the next important catch during this year. Though glass fish (*Kurtus indicus*) occurred in almost all the catches, when compared with the landings of the previous year there was an appreciable decrease in the catch.

The activities of the fishing trawlers were confined to Western channel, S.W. of Puri coast, mouth of Chilka off Devi and off Prachi, Black Pagoda, off Mahanadi and False point at a depth of 3–30 fathoms. Off Devi and Prachi river-mouths were most frequently fished.

Biology of Kurtus indicus.—Samples of glass fish (*Kurtus indicus*) were collected from the West Bengal Fisheries Trawlers K II–V from off Devi and Prachi river-mouth, Black Pagoda and off Mahanadi river. The predominance of this fish was noted in Devi and Prachi river at a depth of 8–20 fathoms. A total number of 421 specimens were examined, ranging from 48–122 mm. in length. Nearly 60% of the specimen were females in the immature stage. The analyses of the stomach contents revealed that these fishes feed more on crustacea such as species of *Acetes*, *Squilla*, Penæus and Cumaceans.

Though *K. indicus* occurs in almost all the months the peak period of its landing was during January when it formed more than 1/12 of the catch. In the month of April it was landed in very small quantity.

Biology of Sciæna glauca.—The fishery of this species during the year 1959–60 was good and of the total landings of 1,49,767·87 kg. of Sciænids at the shore-base station by the West Bengal Fishery Trawlers about 40% constituted *Sciæna glauca* and the remaining 60% included other species. The peak period in the abundance of Sciænids was observed in the month of January.

Samples collected, both on board the vessels and also from the Shore Base Station, were studied with a view to elucidating various aspects of the biology of the fish. From the length-frequency data collected, it was observed that size-range varied from 45–210 mm. Almost all the specimens of *Sciæna glaucus* measuring less than 134 mm. were found to be immature, those between 135 and 152 mm. were found to be maturing and those beyond 153 mm. were found to be mature. 75% were male and 25% female. 20% were mature, 30% maturing and the remaining 50% immature. The three main types of food items observed in the stomachs of the fish were teleosts,

crustaceans and molluscs. Besides these, polychæte larvæ and sand particles were also observed in fair quantities along with diatoms and hydrozoan remains.

C. *Physiology and Marine Fish Farming*

The dynamics of osmotic regulation in *Tilapia mossambica* were studied. Fish weighing from 0·1–50 kg. were used after acclimation to tap-water, 50% sea-water and sea-water at 15°, 20°, 25°, 30°, 35° and 40° C. The results showed that for a 20 gm. fish the effective range of operation where the osmotic load on metabolism is inversely proportional to the salinity of the environment is within the narrow range of 30–35° C. This indicates that for *Tilapia* a temperature range of 30–35° C. in the environment would be well suited for osmotic regulation.

Field observations on the factors leading to the incursion of countless number of *Chanos* fry into the creek at Pamban indicates that the fry do not confine, within their limits, to any particular food element available there. But their spatial distribution in the creek and their preference for the really warm fringes of the shallow creek indicate that the warm environment is very essential for sustaining their relatively higher metabolic rate. The laboratory findings in which the cold sensitiveness of *Chanos* fry was demonstrated earlier thus finds further support.

In April 1959 the entire stock of fish in the ponds was fished out. The yield varied from 195–455 kg. per hectare in the different ponds as against only a maximum of 220 kg. per hectare during the previous year under more or less the same conditions. *Chanos* had attained an average length of 300 mm. during the year. Although all possible attention had been bestowed in improving the results the low survivial rate of the fish caused by various conditions of the ponds, some of which are beyond control at the present state, have prevented a further increase in yield, while the data indicate a level below the optimum yield.

After the harvest, the ponds were prepared and restocked with *Chanos* fingerlings from the lagoon adjoining the fish farm. The principal objects of the culture experiments during the year have been (1) to compare the growth of the fish without artificial feeding of the fish or manuring of the ponds unlike during the earlier year, and (2) to observe the growth of the fish beyond the first year and to ascertain any practical advantage in this. A fall in the growth rate of the fish as compared to that in the previous year has been indicated so far. This might be largely accounted for by the absence of artificial enrichment of the ponds and the lack of adequate fish food. The results thus point towards the need for some kind of artificial enrich-

ment of the ponds to improve the normally available conditions. As regards the practical aspects of culturing the fish in these ponds beyond one growing season, the 1960-61 data will have to be awaited.

Preliminary trials on the possibilities of having smaller separate compartments in the same site for field experiments on nursery management have been started.

IV. Marine Biology

A. *Planktological Investigations*

(*a*) *At Kandla.*—The work on planktological condition of the Kandla creek was started in August 1958 and was in progress during the year. In the zooplankton the common forms present were *Acartia*, *Labidocera*, *Centropages*, *Eucalanus*, Pseudodiaptomids, *Rhincalanus*, *Euterpina*, *Oithona*, *Corycæus*, crustacean eggs and larvae and bivalve, gastropod, echinoderm and polychæte larvae and tintinnids. Fish eggs and larvae were also observed in August–November and then again from February-April. Medusæ and Protozoans were present in collections during June–August or September. Copepods were in abundance in August, February and April, whereas crustacean larvae reached their peak in April followed by minor rise in July. Chætognaths appeared in moderate numbers in collections during November–March.

(*b*) *At Karwar.*—Plankton displacement volume showed that the post-monsoon months are the most produc ive and that showed maximum production in the North Kanara Coast and Ankola the minimum zooplankton population was richer towards the south and more of the phytoplankton dominance is met with at Karwar and Chendia.

Primary phytoplankton maximum was in the month of September and there was also a secondary peak in January. Diatoms were found to bloom only once during the period of observation, in September at Karwar and the important species were *Fragilaria oceanica* and *Nitzschia*. A slight dominance of diatoms observed at Kumta in August was cont ibuted by *F. oceanica* and *Thalassiothrix* sp. In Chendia the dominant forms in the peak period were *Nitzschia*, *Thalassiothrix frauenfeldii* and *Chætoceros* spp. *Chætroceros* spp. were the dominant form at all centres during the secondary peak period. *Coscinodiscus* spp. were found to occur all through the year though only in small numbers. *Trichodesmium* sp., which was found in April, disappeared in May and appeared again in January–March, but was never found to dominate at any place except at Chendia, where it showed minor blooms. Collections from Chendia were very rich in dinoflagellates

comprising mostly of *Ceratium tripos*, *C. fusus* and *C. furca*, all of them appearing later at other places as minor constituents. The rise thus seen continued later at all centres and by December–February *Ceratium massiliense*, *C. macroceros*, *C. vultur* and *C. trichoceros* were common. *Ceratium dens* and *C. tripodioides* occurred in still less quantity. Dinophysids and Peridinians were rare at Karwar and Ankola while tintinnids occurred only in the post-monsoon period.

Evadne were common in September, whereas *Penilia* dominated later. Copepods were abundant during September–October with *Acrocalanus* and *Oithona* sp. as major constituents. At Kumta *Acarita* was dominating. *Sagitta enflata* was dominant at Karwar and Chendia, whereas at Ankola and Kumta, *S. bedotei* seemed more predominant.

Appendicularians were quite common at Karwar and they were found dwindling in numbers towards the south. Various planktonic larvæ were abundant in November–February.

Fish eggs and larvae were most frequent in August–October. Clupeoid and Carangid eggs and larvae were common among the samples. Eggs and larvae of eels were also found.

(*c*) *At Mangalore*.—The analysis of plankton collected from 4-fathom area of Ullal revealed that plankton was poor from June–September 1959. During April and December 1959, January and February 1960, Plankton volumes were high. During the other months of the year the displacement volumes were moderate.

The monsoon phytoplankton bloom was not observed during this year. Among diatoms *Coscinodiscus* spp., *Chætoceros* spp., *Thalassiothrix* sp. and *Hemidiscus* sp. were poorly represented during the monsoon period. The diatom *Fragilaria oceanica* in abundance was observed in August. In November, due to swarming of *Noctiluca* a minor red-water phenomenon was observed in the inshore waters. An almost exclusive Radiolaria swarm was noticed in December as in the previous year. A phytoplankton bloom in lesser magnitude was recorded in January 1960. The common diatoms were *Coscinodiscus*, *Biddulphia*, *Thalassiothrix* and *Bellarochea* sp., *Trichodesmium* sp. *Noctiluca* continued to be present from January–March in appreciable numbers.

Lucifer, cladocera and copepods were dominant from April–July 1959. In August and September, penæiod zoea, fish larvae, and copepods were dominant. From October–December, cladocera and copepods were dominant. From January–March 1960, larvae occurred in swarms only in May

1960. Hydromedusæ, ctenophores, *Sagitta*, *Oikopleura*, cirripede nauplii, brachyuran zoea, were all minor constituents of the plankton.

(*d*) *At Kozhikode.*—During the year under report, studies on the magnitude of standing crop of phytoplankton were conducted with the net collections and sediments obtained by centrifugation. The seasonal cycle of phytoplankton was more or less of the same pattern as in the previous years, with a rich but short primary bloom during the south-west monsoon attaining its peak in August, and a secondary bloom of medium intensity during January–March, which was absent for the last two years. The standing crop in general was better than that of the preceding year and the poorest period was November–December.

Fragilaria oceanica was abundant in collections after the primary bloom, but became scarce quickly. This year its bloom was not a sustained one. *Noctiluca miliaris* was present throughout the monsoon season but was rarely abundant as to discolour the water. During the hotter months, swarms of *Trichodesmium* and *Zooxanthellæ* were sometimes seen.

Quantitative data on the fluctuations in the pigment units showed, that the magnitude of the crop was generally rich. It is also indicated that there might be an equally rich standing crop of nanoplankton. The estimation of the organic production in the sea by the 'dark and clear' bottle method was initiated.

Investigations on the possible relation between polychætes and bottom fisheries, with special reference to *Cynoglossus* fishery, were started. Stomach contents of *C. semifasciatus* obtained from landing grounds at Vellayil and from Departmental hauls were examined. Young of polychætes appeared suddenly in the bottom mud on 29th September. The 2-fathom area was the richest throughout, being dominated by *Prionospio pinnata* until December and by a mud-borrowing Pholadid during December. Adults of *P. pinnata* were never found in the area studied.

The plankton samples taken were poor in polychætes. Pelagic phases of *P. pinnata* were common during September–October. Polynoid larvae were observed during October and *Loimia* larvæ during December–January.

The *Cynoglossus* fishery was not good this year at Calicut. It commenced considerably late (during the last week of September) probably owing to the unusual prolongation of monsoonic weather. This fish was found to feed actively during the commencement of the fishery. In later months (January onwards) the stomachs were mostly empty. During September–November *Prionospio pinnata* was the dominant element in the stomach

contents (as well as in the bottom mud) and during December a mud-borrowing Pholadid (in the stomachs of *C. semifasciatus* as well as in the bottom mud). Larvae of *Pectinaria* were found in the stomachs in appreciable numbers during March; young ones of *Pectinaria* have been found in the bottom mud since February. Although the bottom fauna was almost completely depleted by the beginning of February, young ones of *C. semifasciatus* appeared in small numbers in the *paithu-vala* catches of February and March. The above observations are interesting since they strongly suggest that this bottom-feeding fish is not a selective feeder.

(*e*) *At Mandapam.*—Studies on organic production from six stations in the Gulf of Mannar were continued. Part of the data collected from the original station were processed. It was found that the magnitude of gross production for the two years from July 1957 was almost the same, in spite of monthly variations and shifts in the periods of maxima.

Studies on the plankton of the inshore waters off Mandapam were continued. The salient features of the plankton were:

1. The summer bloom of phytoplankton started as usual but the magnitude of standing crop seemed to be noticeably low, particularly in the Gulf of Mannar during the season. The phytoplanktonic dominance, as usual, continued up to October in Palk Bay, while it was only for a relatively shorter duration in the Gulf of Mannar.

2. There was a bloom of *Trichodesmium* in the Gulf of Mannar early in May.

3. During the first week of November there was a swarming of *Lucifer* in the Gulf of Mannar, while *Creser's acicula* swarmed in Palk Bay and the Gulf of Mannar during the second and third weeks respectively. By the end of November *Pleurobrachia* appeared in large numbers in Palk Bay and by the beginning of December they were common in the Gulf of Mannar. Trends in the species composition of copepods occurring in the inshore waters of the Gulf of Mannar were studied.

Studies on the chætognaths of the Gulf of Mannar and Palk Bay for 1954–58 were made. The analysis of the samples were completed and the data were studied in relation to the hydrographical conditions.

The chætognaths from Plankton collections made by R.V. Kalava during three cruises to the Laccadives were studied. After a cursory examination of the material, 18 species of chætognaths belonging to the genera *Sagitta*, *Krohnitta*, *Eukhronia* and *Petrosagitta* were reported. A very

interesting feature noted during the work is the very high incidence of parasites in these arrow worms.

Eggs of *Hemirhamphus* sp. were collected and attempts were made to rear them in the aquarium. Only a few of the eggs hatched out and it was possible to keep the larvae alive only for four days. Attempts were also made on a few occasions to rear the planktonic eggs in the aquarium tanks without much success.

(*f*) *At Madras.*—During the year under report work was started since June 1959 on the investigation of the plankton from all respects, particularly phytoplankton, on the waters off Madras. The pigment content of the water, displacement volume of plankton and dry-weight were all recorded besides noting the nature of the flora and fauna.

Except for brief periods, zooplankton has been dominant as regards bulk during most of the period. It is possible there is a seasonal fluctuation but the data on hand a e not sufficient to warrant conclusions. Some relevant data (monthly averages) recorded are given below:

	Harvey unit	Vol. ml.	Dry wt. mgm.	Harvey unit	Vol. ml.	Dry wt. m.gm.
I. Predominantly phytoplankton	13,920	9·7	467·5	298	3·3	202·3
II. Mixed plankton surface	..	37·6	1627·4	..	9·5	288·9
III. Mixed plankton bottom	..	40·5	1168·4	..	6·0	246·9
IV. Predominantly zooplankton	..	39·6	1315·3	..	7·3	328·3

B. *Oceanographical Studies*

(*a*) *At Bombay.*—During the year under report, hydrological observations were continued at Light House (L.H.) and Floating Light Vessel (F.L.V.) Stations near Bombay. At F.L.V. the mean salinity was 33·69‰, while at L.H. it was 31·81‰. The mean values for dissolved oxygen, inorganic phosphate and total phosphorus at F.L.V. were 4·0 ml. l., 0·49 μg. at P l. and 1·36 μ, at P l. respectively. The corresponding values at L.H. were respectively 4·3 ml. l., 0·84 μ at P l. and 1·79 μ at P l. Surface chlorophyll at Fl.L.V. ranged from 0·50-1·80 μg. l., with a mean of 1·00 μg. l.,

corresponding to a mean standing crop of phytoplankton equivalent to 27 mg. of carbon per cubic metre of sea-water.

In addition, vertical distribution studies were carried out at F.L.V. during June–December 1959. The results indicated the following ranges in integral mean concentrations of chemical constituents: salinity, 34·30–35·89; dissolved oxygen, 2·2–4·1 ml./l; inorganic phosphate, 0·26–0·76/μg. at P/l., and total phosphorus, 0·93–1·88/μg. at P/l.

With the aim of evolving a simple field method for phosphate "surveys", an attempt was made to extract the Molybdenum Blue in which form phosphate is usually estimated. It was found possible to develop a procedure in which the final blue colour is stable for 8 days, the optical extinction (in 1 cm. cell) per microgram phosphorus being 0·1.

(*b*) *At Karwar.*—Temperature was generally low during July–September which coincides with the South-West Monsoon. In the post-monsoon period it rose constantly marking a slight fall in October and again rose to have a secondary fall in January. Lowest record of temperature at Karwar was observed in the first part of August, whereas towards the south it was observed in succession at Chendia, Ankola and Kumta, in the second half of August, in the first fortnight of September and in October respectively. pH and salinity were also on the decline in the South-West Monsoon period, Karwar being considerably affected due to the influx of freshwater. Decrease of pH at Chendia and Ankola was only slight. Dissolved oxygen content was high during July–August. In Chendia and Ankola high concentration of this was in the month of September only. Phosphates remained low throughout but nitrites showed a little peak in August and another one in March. Concentration of silicates were very high at Karwar diminishing smoothly and successively towards the south in the North Kanara Coast.

(*c*) *At Mangalore.*—In April and May 1959, the surface temperature of sea-water was high and so also the salinity value, *i.e.*, 36·0‰. However, both values declined considerably during the monsoon period. In August the salinity was lowest. From September onwards the water temperature, pH and salinity values gradually increased.

(*d*) *At Kozhikode.*—Studies on the seasonal changes in the hydrological factors of the inshore and offshore waters of the Calicut coast were continued. Offshore collections were totally interrupted from June–August due to bad weather.

In general, the temperature of the inshore water was higher than that of offshore waters in November, January and February and lower during

the rest of the period, excepting in April and October when it remained the same. Surface salinity of the inshore waters was higher in April, October, November, February and March and lower during the rest of the period than of offshore waters. Excepting in April the bottom salinity was always higher in offshore waters. Surface phosphates were lower in the inshore area than in offshore area during the period from October–December and higher in the rest of the period and except in October, bottom phosphates were always higher in offshore waters. Surface silicates of the inshore environment were lower than of offshore one from October–February and higher during the rest of the period; except in October bottom phosphates were always higher in offshore waters. Nitrite cont nt of the inshore waters was in general lower than that of offshore waters. pH of both the waters remained more or less same. Surface oxygen of the inshore waters was higher than that of offshore waters in April, October, November, December and January and lower during the rest of the period; the bottom oxygen was higher in the inshore area from November–March and lower during the rest of the period. Surface total phosphorus of the inshore environment was lower than that of offshore one in April, December and January, March and higher during the rest of the period and except in the months of April and January, bottom total phosphorus was always higher in the inshore waters.

(*e*) *At Ernakulam.*—During the year under review, oceanographical investigations were carried out in the waters of the Arabian Sea along the South-West Coast of India and also the waters around the Laccadive Islands.

During January–February 1959, the shelf was occupied by more or less isothermal water down to 75 m. The waters were also well oxygenated. From the vertical temperature structure it is seen that the thermocline was below 100 m. and in some stations, the upper limit of the discontinuity layer corresponded to the 150 m. level. Stable conditions were observed in the months of March and April in the shelf waters. In the month of May 1959, typical pre-south-west monsoon conditions were seen. The temperature continued to be high in the whole of the waters of the shelf and was more or less uniform in the upper layers.

From June–September 1959 the active period of the South-West Monsoon, the shelf along the coast was occupied by water of low temperature, low oxygen content and rather high salinity. This was particularly seen during the latter part of the monsoon, in the whole of the shelf except in the shallow, near-shore waters. The thermocline and the oxygen-poor layer had both shown an upward trend and by the end of September, except for a thin layer of 10 m. at the surface, the entire body of water was of low temperature,

high salinity and very low oxygen content of less than 0·5 ml./l. All these point to the presence of upwelling at this time of the year and an analysis of wind records show favourable winds for at least part of the period.

The conditions during October–December 1959 indicate a gradual change-over from the monsoon conditions. In early October the surface temperature was low. The thermocline continued to be shallow and the oxygen-poor layer fairly high up indicating the persistence of upwelling. In late October and November the downward migration of the discontinuity layer as well as layer of oxygen-minimum had commenced and there is evidence of "down-welling".

The conditions in January 1960 were more or less similar to those of the same month last year. By February the salinity had shown a rising trend while the temperature was more or less the same as in January. Oxygen content was quite high down to 100 m., below which there was a very sharp decrease to values less than 0·5 ml./l. The thermocline was below 90 m. and in some observed at 120 m. The sinking, which had commenced in December, was still present in February.

In the Laccadives offshore waters the temperature distribution showed the presence of more or less isothermal water down to 50 m. The discontinuity layer was observed between 75 and 150 m. A salinity maximum was seen to occur within a tongue of high saline water at about 100 m. From the nature of the density surfaces and the computed geopotential anomalies it is inferred that there are circulatory water movements around the islands at practically all levels down to 500 m. The layer of oxygen minimum was seen to be present below 150 m. extending down even to 1,000 m.

The characteristic features of the waters near Cochin noticed during the post-monsoon season are (1) the surface salinity of the waters was low throughout the season sometimes going as low as 32‰, (2) the temperature of the waters had decreased and the subsurface layers exhibited high salinity. It is inferred that during this period the whole of the continental shelf is occupied by water which has upwelled from subsurface levels, (3) a characteristic uplift of the thermocline had occurred which was situated at a depth of 75–100 m. normally (for a greater part of the year) being now at about 10–70 m., (4) an examination of the oxygen distribution showed that the dissolved oxygen content of the surface layers off Cochin was uniformly high sometimes even exceeding the saturation value. But there was a steep decrease from about 10–20 m. downwards the values at deeper levels becoming very low.

With still more or less the same features the season proceeds till early October but a transition was conspicuous towards the end of the month and in the following winter. Even in early October upwelling was prevalent and as a consequence the surface temperatures were low. The salinity and dissolved oxygen contents also seem to support the above phenomenon. But towards the end of October there was a marked change. The rapid decrease of the dissolved oxygen content from about 10–20 m. noticed earlier was not prevalent during later October and the discontinuity layer had migrated down and a sharp thermocline was not evident even at 50 m. depth.

The winter characteristics were well developed during December. The temperature had increased and likewise the dissolved oxygen contents also. Even at 50–75 m. the dissolved oxygen values were very near saturation. The layers up to about 50–75 m. were completely mixed, the waters being mostly isothermal. The salinities in the mixed layer also were low. From an examination of the hydrographic data sinking seemed to be prevalent during December in these regions. The thermocline had migrated farther down and was evident only at about 100–50 m. Within the thermocline a salinity maximum had developed which was not found during the previous seasons.

C. *Algology*

During the year under review the taxonomic study of the algæ, collected from the Pearl beds off Tuticorin during the Pearl Fishery of 1958–59, was completed. One new genus of the *Lophothalieæ* was also recorded and this was critically studied.

Since there was no further change in the colonization and stabilization of the algal flora on the experimental boulder in Palk Bay, near Mandapam the observations were since centred on some of the more dominant species such as *Laurencia* and *Spyridia*. An attempt was made to measure the growth rate of the population as a whole in terms of dry weight per square centimetre of substratum surface (measured on a horizontal place), at regular short intervals so as to get an idea of the algal productivity, *i.e.*, the rate of production of material by the algæ from the inorganic material of the sea.

Work on the agar manufacture and resources was continued. *Gracilaria crassa* was found to be an equally good source of high grade agar as *Gelidium* and *Gracilaria lichenoides*. Adequate methods of handling this species as well as *G. corticata* for agar were found out. In the case of the latter addition

of lime was found to increase remarkably the gel strength of the agar. A new method of obtaining colourless agar from *Gelidium* and *Gracilaria* was found. This method also improves the porous texture of these agars. An estimate based on local sea-weed collections and harvesting of the resources in the dominant species of agarophytes of the Pamban and adjoining islands indicated a production of 2·6 m. tons of refined agar.

CENTRAL MARINE FISHERIES
RESEARCH STATION,
Marine Fisheries P.O., Mandapam Camp,
South India,
March, 31, 1960.

S. JONES,
Chief Research Officer.

V. LIST OF PUBLICATIONS DURING THE YEAR 1959–60

1. SEKHARAN, K. V. 1959. Size-groups of *Choodai* taken by different nets and in different localities. *Indian J. Fish.*, **6** (1), 1–29.
2. JONES, S. AND KUMARAN, M. 1959. The fishing industry of Minicoy Island with special reference to the Tuna Fishery. *Ibid.*, **6** (1), 30–57.
3. JAYARAMAN, R., SESHAPPA, G., MOHAMED, K. H. AND BAPAT, S. V. 1959. Observations on the Trawl-Fisheries of the Bombay and Saurashtra Waters, 1949–50 to 1954–55. *Ibid.*, **6** (1), 58–144.
4. JONES, S. 1959. Notes on eggs, larvæ and juveniles of fishes from Indian Waters. II. *Istiophorous gladius* (Broussonat). *Ibid.*, **6** (1), 204–10.
5. RAMA SASTRY, A. A. AND MYRLAND, P. 1959. Distribution of temperature, salinity and density in the Arabian Sea along the South Malabar Coast (South India) during the post-monsoon season. *Ibid.*, **6** (2), 223–55.
6. KRISHNA KARTHA, K. N. 1959. A study of the copepods of the inshore waters of Palk Bay and Gulf of Mannar. *Ibid.*, **6** (2), 256–67.
7. GEORGE, M. J. 1959. Notes on the bionomics of the Prawn, *Metapenæus monoceros*, Fabricius. *Ibid.*, **6** (2), 268–79.
8. NAYAK, P. D. (MISS). 1959. Some aspects of the fishery and biology of *Polydactylus indicus* (Shaw). *Ibid.*, **6** (2), 280–97.
9. UDAYA VARMA TIRUPAD, P. AND GANGADHARA REDDY, C. V. 1959. Seasonal variations of the hydrological factors of the Madras Coastal waters. *Ibid.*, **6** (2), 298–305.
10. VELANKAR, N. K. AND GOVINDAN, T. K. 1959. Preservation of prawns in ice and the assessment of their quality by objective standards. *Ibid*, **6** (2), 306–21.

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14. Dharmamba, M. (Miss). 1959. Studies on the maturation and spawning habits of some common Clupeoids of Lawson's Bay, Waltair. *Ibid.*, **6** (2), 374–88.

15. Varma, R. Prasanna. 1959. Studies on the succession of marine algæ on a fresh substratum in Palk Bay. *Proc. Indian Acad. Sci.*, **49**, 245–63.

16. Prasad, R. Raghu and Tampi, P. R. S. 1959. A note on the first phyllosoma of *Panulinus burgeri* (de Haan). *Ibid.*, **49**, 397–401.

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18. Subrahmanyan, R. 1959. Studies on the phytoplankton of the west coast of India. Part I. Quantitative and qualitative fluctuation of the total phytoplankton crop, the zooplankton crop and their interrelationship, with remarks on the magnitude of the standing crop and production of matter and their relationship to fish landings. *Ibid.*, **50** (3), 115–87.

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26. ———. 1959. Research Vessel "Kalava" and co-operative oceanographic investigations in Indian waters. *J. Mar. biol. Assn. India*, **1** (1), 1–6.

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28. THIVY, F. (Mrs.). 1959. On the morphology of the Gametophytic generation of *Padina gymnospora* (Kuetz.) Vickers. *Ibid.*, **1** (1), 69–76.

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35. RAMACHANDRAN NAIR, P. V. 1959. New records of marine planktonic diatoms from the west coast of India. *Ibid.*, **1** (1), 96.

36. JONES, S. 1959. An unusual instance of a bird getting trapped by a clam. *Ibid.*, **1** (1), 97.

37. KAMASASTRI, P. V. 1959. Chemical properties and changes during storage of some Indian Ray liver oils. *Curr. Sci.*, **28** (12), 489–90.

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51. Silas, E. G. and Dawson, Egbert. 1959. On the concealing behaviour of the Tigerfish *Therapon jarbua* (Forskal). *Ibid.*, **7** (2), 252.

52. Sankarankutty, C. 1959. A note on the abnormalities in *Thalamita integra*, Dana. *Ibid.*, **1** (2), 254.

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GOVERNMENT OF INDIA
ANNUAL REPORT OF THE CENTRAL INLAND FISHERIES RESEARCH STATION, BARRACKPORE, FOR THE YEAR 1959-60

General

The headquarters of the Central Inland Fisheries Research Station was shifted from Calcutta to its newly constructed permanent buildings at Barrackpore with effect from 1st June 1959. The buildings were formally declared open by Dr. B. C. Roy, Chief Minister of West Bengal, on 17th June 1959. Shri M. V. Krishnappa, Union Deputy Minister for Agriculture, presided on the occasion. The Research Station has been built on an area of about 13 acres of land and the main laboratory building has a floor area of 15,000 sq.ft., excluding corridors and verandahs. The trainees' hostel has a usable floor area of 7,000 sq.ft., and has 25 rooms, a common room, drawing room, etc. 51 residential quarters have been built so far, and a few more are under construction. The new buildings have been constructed at a total cost of about Rs. 13 lakhs.

Substantial progress was achieved during the year in all investigations undertaken by the Research Station. In addition, there was also an all-round expansion of activities of the various sections and units, under both normal and Second Five-Year Plan programmes.

The undermentioned Assistant Research Officers were appointed during the year:

Shri K. L. Sehgal
Dr. (Miss) Eva Mitra
Shri L. N. Mandal
Dr. K. C. Jayaramakrishnan
Shri K. K. Ghosh
Shri S. N. Sengupta
Shri A. N. Ghosh
Shri M. A. Vijayalakshmanan

Shri Hiralal Chaudhuri, Assistant Research Officer (Estuarine Fishery Biology), was relieved of his duties to take up the post of Fisheries Extension

Officer under the Ministry of Food and Agriculture. Shri A. Datta took over as Fisheries Training Superintendent with effect from 14th March 1960.

Shri J. M. David, Administrative Officer, was relieved of his duties to enable him to join the Oil and Natural Gas Commission.

Training

The 12th Session of the Inland Fisheries Training Course conducted during the year under report was attended by 36 candidates, consisting of 2 Colombo Plan Trainees—one each from Thailand and Philippines; 19 Government deputees from the States of Uttar Pradesh, Assam, West Bengal, North East Frontier Agency, Rajasthan, Madhya Pradesh, Orissa, Andhra, Delhi and Bombay; 5 Government stipendiaries from the States of Assam and Manipur and 10 private candidates from the States of Bombay, Uttar Pradesh, West Bengal, Andhra Pradesh, Madhya Pradesh, Punjab and Mysore. In the final examination conducted in January 1960, 2 candidates were placed in the First Class, 18 in the Second Class and 14 in the Third Class.

A short training-*cum*-demonstration course in induced spawning of Major Carps by hormone injection was conducted at the Cuttack Substation from 6th to 16th July 1959.

Deputation

Shri K. H. Alikunhi, deputed for training in Japan under the Colombo Plan, left Calcutta on 28th May 1959 and after a period of successful training, returned to India and resumed duty at Cuttack on 8th September 1959.

Meetings

The Chief Research Officer attended the State Fisheries Directors' Meeting convened by the Ministry of Food and Agriculture on the 16th and 17th April at New Delhi, the inaugural meeting of the Central Board of Fisheries and the meeting of the Standing Fisheries Research Committee at New Delhi in December 1959, and the West Bengal State Advisory Board Meeting at Digha from 10th to 13th January 1960.

Shri K. H. Alikunhi and Shri Hiralal Chaudhuri attended the Sixth Meeting of the Standing Fisheries Research Committee held at Trivandrum from 2nd to 6th April 1959.

F.A.O. Fellows

Mrs. Agnes Cooper Dennis, Lecturer in Biology, University of Liberia and UNESCO Scholar, visited this Research Station during 14th February

1960 to 17th February 1960 and arrangements were made for her training in freshwater biology.

Mr. M. E. Faltas, F.A.O. Fellow from Egypt, whose visit to this Research Station was arranged by the Institute of Agricultural Research Statistics, New Delhi, was afforded necessary facilities and was shown the fishing activities around Calcutta with a view to provide a first-hand knowledge of the fisheries management and methods of collection of official statistics.

F.A.O. Expert

Mr. S. B. Gulbadamov, F.A.O. Gear Technologist, along with the Russian Interpretor Mr. G. A. Semin, was assigned to this Research Station. A programme of work has been arranged for the Expert, and he is now conducting preliminary experiments in deep-water fishing in the Mettur Reservoir. Dr. Y. R. Tripathi, Research Officer (Lacustrine), has been posted as understudy to Mr. Gulbadamov.

Reports

The final report of the Committee on standardisation of names of fishes and fishing subjects was submitted to Government.

Visitors

Shri Krishan Chand, I.C.S., Joint Secretary, Dr. N. K. Panikkar, Fisheries Development Adviser, Shri K. Chidambaram, Assistant Fisheries Development Adviser, Shri V. V. Kalyani, Director of Fisheries, Mysore, Dr. Monmohan Das, Deputy Minister, Ministry of Scientific Research and Cultural Affairs, Shri S. Miskeith, Superintending Engineer of Deep-Sea Fishing Station, Dr. B. N. Chopra, former Fisheries Development Adviser and Consultant, National Council of Applied Economic Research, Dr. L. R. Donaldson, Professor of Fisheries, University of Washington, and Dr. J. K. Thompson, Director, Colombo Plan Bureau visited this Research Station during the year.

Miscellaneous

350 Silver Carp (*Hypophthalmychthys molitrix*) fingerlings received as gift from Japan are being used for experimental studies. 400 Grass Carp (*Ctenopharyngodon idellus*) fry were also imported from Hong Kong for similar investigations. The Research Station took active part in the World Agriculture Fair held at New Delhi. Facilities were rendered to the representatives of Cine Co-operative Ltd., for preparing a documentary film on Pond Culture.

Pond Culture Division

Induced Breeding of Indian Carps

During the 1959 fish breeding season (May to August), work on induced breeding by injection of hormones was taken up at Cuttack and Joysagar. Breeding was successfully induced in all the four major carps Catla, Rohu, Mrigal and Calbasu and commercial production of large number of spawn and fry was achieved for the first time by this method.

The common carp (*Cyprinus carpio*) was found to be a very satisfactory species for year-round collection of pituitary glands, because sexually mature specimens of the species were available throughout the year in the farm ponds. Collection of pituitary glands, was therefore made a routine before mature specimens were sold from the farm. Over 200 glands were collected by this method and the bulk of these was utilised for experiments at Joysagar, Assam. With the kind courtesy of the Fisheries Development Officer, Madhya Pradesh, 510 pituitary glands, mostly from small but mature Mrigals, were collected during May–June 1959 at Gwalior. 264 glands (Rohu 140, Mrigal 117 and Catla 7) were collected at Calcutta and majority of these were utilised in Assam.

The absolute alcohol method was followed for preserving the glands. Part of the material collected was preserved in a refrigerator at low temperature, while the rest was kept at room temperature in order to ascertain whether the hormone potency of the glands will remain unaffected under such conditions.

Fish breeding in Assam commenced from the last week of May. Catla, Rohu and Calbasu were successfully induced to breed. Two female specimens (29 lb. and 12 lb.) bred, each as a result of single injection. The percentage of fertilization of eggs ranged from 32 to 89. A total of 8,70,000 spawn was raised. Besides supplying 2 lakhs of spawn to the Nowgong Centre, 294,000 advanced fry were reared out of the above spawn indicating a survival of 44%. That Catla also can be successfully induced to breed like the other Indian carps is now fully demonstrated. Total production of spawn and advanced fry at the Joysagar Centre during the year was 9,18,000 and 3,02,500 respectively, representing an overall survival of 42%. At Cuttack, routine procedure of keeping selected breeders in smaller ponds, preparation of nurseries for successful rearing of fry, etc., were carried out during May to June. Of the major Indian carps, Mrigal was found to attain maturity earlier in the season than Catla or Rohu and the fish successfully spawned during the second week of June. All the major carps, *viz.*,

Catla, Rohu, Mrigal and Calbasu and the minor carps Bata and Reba spawned during the season as a result of pituitary injections.

Breeding experiments were carried out in tap-water kept in cement cisterns, in stagnant pond-water and also in flowing river-water. Though positive results were obtained under all these conditions, the results in tap-water were comparatively poor. The best results were obtained in flowing river-water. It is proposed to make arrangements for supply of flowing river-water in cisterns in the Killa for further experiments. The breeding experiments were most successful with Rohu, where spawning was induced in 51% of the breeders injected.

The details of spawn and fry produced during the period under report are given below:

Rohu.—21,15,000 hatchlings, which yielded just over 10,00,000 advanced fry and fingerlings valued at approximately Rs. 10,000. Over 90% of these fingerlings were supplied to the Orissa Fisheries Department for stocking purposes. Average survival works out to over 47%.

Mrigal.—Nearly 6,00,000 hatchlings, which yielded about 2,00,000 advanced fry and fingerlings valued at approximately Rs. 2,000. About 60% of these were supplied to the Orissa State Fisheries Department for stocking. The survival works out to 33%.

Catla.—Though 3 specimens of Catla spawned, the percentage of fertilization was very low and only less than 1,000 advanced fry and fingerlings could be obtained.

Non-specificity of the glands to induce spawning was clearly demonstrated this year also. Pituitary glands of *Cyprinus carpio* induced successful spawning in Rohu and Mrigal, those of Rohu induced spawning in Catla, Rohu and Mrigal and the glands of Mrigal induced spawning in Mrigal and Rohu. Pituitary glands stored at room temperature for a period of 2½ to 3 months induce successful spawning at similar doses, as glands stored under low temperature do. Results obtained from experiments carried out with the minor carp *Cirrhina reba*, using pituitary glands from fishes of various stages of maturity, have shown that comparable doses of glands from fishes of earlier stages of maturity do not induce spawning as the glands from mature fishes.

While weather does not appear to be a very important factor in inducing spawning of fish, hot sultry conditions are not conducive to the satisfactory handling of the fertilized eggs and their proper hatching. It appears from observations on fishes injected and kept in cisterns that when female

starts laying eggs and the male is not active enough to fertilise them, stripping could be resorted to for successful fertilization.

Observations have also indicated that fry produced from induced breeding mature normally. Experiments for inducing maturity earlier than the normal season are in progress.

Breeding and Propagation of the Common Carp Cyprinus carpio

On the basis of detailed information furnished by this Research Station on the biology and growth of this species, the Fisheries Research Committee of the Government of India recommended in April 1959 that the fish be introduced throughout the country and also desired the States' Departments of Fisheries to take up breeding and cultivation of the species. The following supplies were made during the year under report to different agencies:

Statistical Institute, Calcutta		25000 (Spawn)
Department of Fisheries, West Bengal (through the Director of Fisheries, Orissa)	..	500 ($2\frac{1}{2}$ to 3 ″)
Fisheries Officer, Tripura	..	25,000 (1 to $1\frac{1}{2}$″)
Assistant Director of Fisheries, Nellore, Andhra Pradesh	..	4,300 (1 to $1\frac{1}{4}$″)
Fisheries Officer, Raipur, Madhya Pradesh	..	7,000 (1 to $1\frac{1}{2}$″)
Shri A. Bari, Barang, through Director of Fisheries, Orissa	..	5,000 (1 to $1\frac{1}{2}$″)
Assistant Fisheries Extension Officer, Mandapam Camp	..	800 ($1\frac{1}{2}$ to 2 ″)
St. Joseph's Convent, Vishakhapatnam	..	200 (1 to $1\frac{1}{2}$″)
Orissa Fisheries Department	..	46,100 ($\frac{3}{4}$ to $1\frac{1}{4}$″)

Besides supplying a few breeders of common carp to the Barang Fish Farm, Orissa, the breeding technique was successfully demonstrated at the Barang and Sambalpur fish farms. Intensive breeding of the species was taken up at Cuttack and during January to March 1960, a little over 10 million fry (about 200 batis), 2 to 3 days old after hatching, valued at about Rs. 4,020, were supplied to the State Department.

Breeding of the common carp was carried out in the cement cisterns containing tap and well-water. Soon after spawning, weeds with attached eggs were transferred to ponds, where they were distributed in hapas. To ensure high percentage of fertilization of the eggs, 3 to 4 males were often

introduced along with a single female. Percentage of hatching depended on the hatching space provided. Breeding generally took place within 12 to 36 hours after the introduction of the fishes in the cisterns. Breeding was successfully carried out in hapas fixed in ponds. With proper thinning of weeds, the rate of hatching was found to be better than in cisterns. Natural spawning of fish in stocking ponds is generally rare. However, if the fish are kept in hapas and necessary weeds are introduced, they readily spawn.

Natural spawning was observed in the Killa channel, two of the rearing ponds and in a prepared nursery pond. Weeds with attached eggs were collected from the channel and rearing ponds and by hatching of the eggs in cisterns and ponds nearly a lakh of fry could be obtained. However, though the bulk of the eggs laid in the channel and rearing ponds hatched, hardly any fry could be seen presumably due to their having been preyed upon by predators. In the prepared nursery pond some of the fry survived, yielding a little over 1,000 early fingerlings. These observations are in conformity with findings already reported and indicate that for proper propagation of common carp, provision of breeding facilities is essential.

In the Bangkok strain (Eastern Strain) of common carp, colour varieties are common. Preliminary work on selective breeding of some of the colour variations of common carp has been taken up recently.

Certain preliminary observations on the size of eggs and hatchlings in relation to the size of the breeding female and the relative growth and survival of fry from fishes of different sizes have been made.

In a field experiment lasting for $4\frac{1}{2}$ months, Mrigal and common carp of comparable size were stocked in equal numbers and it was found that the average survival of common carp was 83·4%, while that of Rohu and Mrigal was only 67% and 54·5% respectively. The production of common carp was more than the combined production of Rohu and Mrigal. Further experiments in this line have been taken up.

Observations on the mirror carp (Cyprinus carpio *var.* specularis)

The mirror carp was introduced into India in 1939 and since then it has been thriving in the relatively cold upland waters. Though the fish has been brought down to the plains and found to grow rapidly in the tropical habitat, it was not breeding in the lower elevations. To ascertain whether the fish could be induced to breed at sea-level by adopting the breeding techniques followed in South-East Asia for the scale carp, consignments of mirror carp fingerlings were brought from Shillong to Cuttack

and Joysagar. When these fishes became mature, they were induced to breed in cisterns and hapas by adopting the same technique as used for the scale carps. During the period under report the fish bred twice at Cuttack, producing 1,40,000 fry at Cuttack and twice at Joysagar, yielding 38,000 fry. Seven months' old males of the species were observed to have become generally mature at the Cuttack farm. 1,000 fingerlings were supplied to the Orissa Fisheries Department for stocking in Koraput at an elevation of about 4,000 ft. The successful breeding of mirror carp at Cuttack and Joysagar clearly demonstrates that when proper breeding facilities are provided, the fish breeds in the plains also.

Observations on Chinese Carps

Consignments of 400 fingerlings each of the grass carp (*Ctenopharyngodon idellus*) and the silver carp (*Hypophthalmychthys molitrix*) were brought from Hong Kong and Tokyo respectively and are being studied at Cuttack. The survival of Silver carp during September 1959 to March 1960 has been 64% and that of Grass carp during a 3·5 months' period 30%. The growth of the former has been very satisfactory, the maximum size attained so far being 47·2 cm. (weight 1·4 kg.). 114 specimens, weighing 0·4 kg. each, have been stocked in the Killa channel for rapid growth. The maximum size attained by Silver carps has been only 19·4 cm. (average weight being 37 gm.).

The Chinese carps do not breed in ponds. As importing fry every year is not practicable, the fish are being provided with optimal conditions for rapid growth and early attainment of maturity, so that it could be ascertained whether they could be induced to breed in ponds. Stocked at the rate of 1,000 per acre, the Silver carps showed higher rate of survival than Catla. The weight increased by 234%, whereas the corresponding increase in weight of Catla was only 139%. Investigations are being continued in this direction.

Tilapia Investigations

A field experiment in 20 ponds at Puri, designed to ascertain the role of Tilapia when stocked with various combinations of carps, was completed during the period under report. The final results are in agreement with the earlier findings that presence of Tilapia markedly affects the growth and survival of Mrigal. Because of intensive breeding Tilapia multiplies rapidly in ponds which soon get overpopulated, resulting in an abundance of very small fish in ponds. Such fish have no market value. To find out whether by frequent harvesting of the large fish, the smaller ones could be made to

grow and yield marketable fish, observations were continued in a one-acre stocking pond in Killa. It was found that the size and yield considerably improved with weekly harvesting of large fish. The market value of Tilapia is however only about half that of carps.

Some observations on mono-sex culture of male Tilapia were also made. Though fish exceeding 30 cm. in length and weighing upto 0·68 kg. could be produced, the quantity of fish produced appeared to be low. The rate of stocking was 3,000/ha. The larger fish have a better market value than the smaller ones and attempts are being made to find out whether mono-sex culture of Tilapia could be taken up as a supplementary crop in carp ponds.

Fresh experiments on the possible use of Tilapia as a forage fish for murrel were also taken up. Test samplings indicate that while in the control ponds different size-groups of Tilapia occur and that they multiply rapidly, there is a definite check on the production of the young in ponds where murrels have also been introduced.

Fish Culture in Paddy Fields

Only one experiment could be taken up during the year at the Central Rice Research Institute plots. Fingerlings of Common carp and Rohu were stocked in 6 plots at the rate of 2,500 per hectare, but heavy rains and consequent overflooding of the plots soon after stocking, as also draught conditions towards the end of the year have necessitated fresh observations to be made.

A survey of the soil, water and fish-food conditions in selected deep water paddy fields in the districts of Cuttack, Puri, Ganjam, Sambalpur, Sundergarh and Bhawanipatna was taken up. The fields at Puri and Bhubaneswar appear to be poorer than those at Sambalpur, Kujang and Berhampur. Plankton in fields at all the places is poor. These data seem to corroborate earlier findings that the paddy fields cannot be classified as a good environment for fish production.

Soil Composition and Fish Production

In order to study the soil conditions and water qualities of fish ponds in various parts of India, a random survey has been initiated. Samples from demonstration fish ponds in Howrah and 24 Parganas showed the soil reaction to be slightly acidic or slightly alkaline, pH ranging from 6·6 to 7·8; available nitrogen quite fair (21·0 to 52·0 mg./100 gm.) and available phosphorus to be varying from a low (2·0 mg./100 gm.) to a fairly high concentration (14·0 mg./100 gm.). Data on fish production

furnished by fish farmers indicate that generally available phosphorus has a direct relation with yield of fish.

The relation between available nutrient status of piscicultural soils and production of fish was also studied by conducting a series of experiments in selected tanks with different soil conditions. Results of analyses showed that soil reaction continued to be slightly acidic or slightly alkaline, nitrogen content was quite fair, while available phosphorus varied from 'very poor' to 'fairly high'. The data obtained confirmed last year's observations that in slightly acidic or slightly alkaline soils with a fair concentration of available nitrogen, available soil phosphorus is likely to play an important role in determining the production of the tanks.

Investigations have been taken up in Choudwar fish farm in six selected tanks to study the effect of trace elements when applied with inorganic fertilizers. The tanks have been divided into three sets of two each. Keeping one set as control, one set has been treated with superphosphate alone and the other set with superphosphate and salts of trace elements Manganese, Copper and Iron. Chemical quality of them, inclusive of the concentrations of the trace elements added, were determined regularly and organic productivity was assessed by gravimetric estimation of total plankton. The fluctuation in concentration of trace elements in aquatic phase was rather irregular. However it was observed that for Manganese the decrease in concentration was rather slow in treated ponds. It was also noticed that just after treatment there was an abrupt increase of plankton and that plankton concentration was generally maximum in ponds treated with trace elements.

With a view to determine whether low-nutrient acid soils could be corrected by application of organic and inorganic fertilisers with lime, an experiment has been taken up in 24 ponds at Lingipur. The ponds have been divided into eight sets of three each and keeping one set as control, they have been treated with different combinations of lime and fertiliser. The tanks were stocked with carp fingerlings at a uniform rate and the response of different types of treatment was assessed by the production of fish. Chemical examination of water and soil showed that liming did not improve the alkalinity of water permanently. There was no marked increase in soil pH by lime treatment. This showed that the reserve soil acidity was rather high in these ponds. It was observed that excepting treatment with low lime, all others showed an increase in production, maximum being with low lime + high phosphate and high lime + high phosphate.

Weed Control Investigations

Field applications of urea indicated that *Hydrilla* and unwanted fish in the water were completely eliminated at concentrations of 250 and 330 p.p.m., and that roughly a third of the urea was converted into ammoniacal nitrogen by the third or fourth day after treatment, which lead to the conclusion that probably ammonia was the active principle involved in the eradication of the weed and weed fish. Hence experiments were carried out using liquor ammonia as well as a mixture of ammonium sulphate and quicklime. Complete kill of *Hydrilla* and *Naias* were obtained with 20 p.p.m. or more of ammonia (N). 10 p.p.m. also gave a fairly good kill. Field trials were carried out with anhydrous ammonia available in steel cylinders in the liquefied condition. A plot of about 0·24 hectares and 1·52 metres deep was effectively cleared of the weeds with 34 kgm. of ammonia gas, about 36 man-hours being required for a supplementary clearance of remnants of weeds. Larger fish in the treated plot were saved by sectional treatment of the choked area. Unlike poisonous chemicals such as sodium arsenite, urea and ammonia have the additional advantages of being combined fertilisers, fish poisons and weedicides, which renders them much cheaper to use. The action of ammonia on aquatic weeds appears to be one of direct toxicity, as indicated by the stoppage of photosynthetic activity.

Further experiments were carried out in the laboratory with various soil sterilising chemicals at high rates of application to see whether any of them could be effective. The extent of sterilisation obtained was determined by the capacity of the chemicals to suppress the germination of the winter buds of *Hydrilla*. None of the chemicals except sodium arsenite gave complete suppression.

It has been found that a mixture of equal quantities of sodium metabisulphite and sulphuric acid kills *Hydrilla* completely at a dosage of 75 p.p.m., the lethal action being due to the release of about 50 p.p.m. of sulphur dioxide. At a dosage of 50 p.p.m. of acid and 34 p.p.m. of salt serious damage to the plant was achieved. Fish are not killed at both these concentrations.

It is generally known that high doses of trace elements often prove toxic to plants. To see whether this is true of aquatic plants as well, some laboratory experiments were carried out with manganese and iron. Manganese was applied at the rate of 20 p.p.m. on healthy *Hydrilla* kept in glass jars containing water, but the plants were not affected. Iron was applied in the form of ferrous sulphate alone, as well as mixed with the activators

ammonium sulphate or sodium nitrate or with acids, the rates of application being 50–100 p.p.m. In both cases there was only partial effect on *Hydrilla* grown on a soil-water medium.

Laboratory, yard and field experiments with the hormone weedicides "Fernoxone" and "Dicotox" showed that *Wolffia* and *Ottelia* are killed by fernoxone at 25 kgm. per hectare, *Nelumbium* requires a second treatment before it is completely killed, *Ipomœa* treated with 5–10 kgm. per hectare and *Pistia* with 15 to 25 kgm. per hectare of these weedicides showed only defoliation of the leaves, the unaffected stems giving rise to fresh leaves at the end of the four weeks. *Hydrilla* is not killed by fernoxone at 20, 30, 50, 75 and 100 kgm. per hectare even when the water level is lowered to expose the trips of shoots.

Field plots of *Pistia* treated with diesel oil and power kerosene at 600 litres per hectare killed about 80% of the leaves initially, but the plant regenerated vigorously from unaffected stems and plants at the end of 3 to 4 weeks. Monochlorobenzene emulsified in soap killed *Hydrilla* completely at 350 p.p.m. At lower concentrations the kill was not complete. 100 p.p.m. of 'atlacide' with 25 p.p.m. of sulphuric acid gave encouraging results on *Hydrilla*.

Autecological studies on *Ottelia* were made throughout the year in four ponds at Cuttack. Data obtained indicate that *Ottelia* grows best under the following conditions:

Average yield of tomatoes per plant

	Depth of water (metres)	Temperature °C.	Turbidity p.p.m.	pH	T. alk. p.p.m.	Cl. p.p.m.	NO_3 p.p.m.	PO_4 p.p.m.
Range ..	0·45–1·82	25·3–34·7	20–110	6·8–8·9	54–180	9–171	9·05–0·70	0·01–2·80

A single *Ottelia* plant produces on the average about 20,000 seeds. Studies carried out in the laboratory and yard indicate that there is 50% germination under crowded and anaerobic conditions, 5% germination under aerobic conditions and 60 to 100% in containers with soil from 0·75% to 1 metre deep in cement cisterns.

Laboratory studies on the period of viability of *Hydrilla* turions indicated that they remain viable in pond-water and wet pond mud at the end of six months, whereas they die in dry pond mud, dry sand and dry cotton wool.

Observations were continued on five sections of the Killa moat and a deep tank to study the effect of algal blooms in the suppression of submerged weeds.

An experiment was carried out to assess the comparative value of composts from various weeds and the results obtained are given below:

	gm.
Water hyacinth	6015
Hydrilla ..	2353
Hydrilla + *Pistia* ..	2265
Pistia ..	1931
Control ..	2290

In order to obtain information on the nature of weeds and the extent and causes of weed infestation in cultivable waters of Orissa, a sample survey of the inland waters was carried out during the year. Preliminary findings from the survey are as follows:

Type of water	Number surveyed	Total area covered (hectares)	Area infested with weeds (hectares)	% infestation in area
Farm ponds ..	53	39·25	15·75	40·0
Public tanks ..	56	34·41	20·53	60·0
Reservoirs and lakes	6	350·40	259·32	74·0
Swamps and derelict tanks ..	10	127·00	119·56	94·5
Total ..	125	551·06	413·15	75·0

Riverine and Lacustrine Division

Catch Statistics and Disposition of Fisheries in the Ganga River System

Data on monthly production and average catch per day obtained from the Ganga and Jumna are summarised and tabulated on the next page.

	Ganga		Jumna	
	Monthly (kgm.)	Daily (kgm.)	Monthly (kgm.)	Daily (kgm.)
1959—				
April ..	91035·55	3034·52	94977·63	3166·25
May ..	81104·38	2617·43	46284·06	1493·03
June ..	98232·30	3274·40	108967·27	3632·24
July ..	94453·88	3046·90	98427·33	3175·08
August ..	33193·79	1070·77	13946·95	449·90
September ..	54518·80	1817·29	21209·61	706·99
October ..	79611·13	2568·10	18118·81	584·48
November ..	69363·07	2312·10	25118·81	837·29
December ..	86897·57	2803·15	28424·75	916·93
1960—				
January ..	62249·60	2008·05	21275·61	686·31
February ..	77632·09	2676·97	47791·64	1647·99
March ..	71155·26	2295·33	20783·95	670·45

The composition of the catches is as under:

	Ganga (kgm.)	Jumna (kgm.)
Major carps		
(*Catla catla, Cirrhina mrigala, Labeo rohita* and *L. calbasu*) ..	224795·67	282834·06
Major cat-fishes		
(*Mystus aor, M. seenghala, Wallago attu, Silonia silondia, Pangasius pangasius, Rita rita* and *Bagarius bagarius*) ..	263116·45	18311·80
Minor cat-fishes		
(*Clupisoma garua, Eutropiichthys vacha, Ailia coila,* etc.)	55866·72	12552·84

	Ganga (kgm.)	Jumna (kgm.)
Hilsa	154750·33	14343·70
Murrel ..	1257·05	2373·42
Featherbacks (*Notopterus chitala* and *N. notopterus*) ..	18732·72	10790·08
F. W. Rays (*Dasyatis fluviatilis*) ..	9718·58	314·45
Prawns (*Palæmon, Leander* and *Caridina* spp.) ..	21907·74	362·48
Tortoise ..	9261·09	..
Miscellaneous ..	146154·40	19988·33

Catch Statistics of Narbada River at Hoshangabad

A 30-mile stretch of the Narbada river has been selected for intensive study. 40,000 kgm. of fish valued at about Rs. 50,000 were estimated to have been landed in this stretch during the year under report. Mahaseer (*Tor* spp.), *Labeo fimbriatus* and *Rita pavimentata* formed the major part of landings (26·7, 19·7 and 14·3%). Mahaseer dominated in the catches followed by *Labeo fimbriatus* and *Wallago attu*, *Rita pavimentata* and *M. seenghala*.

Cast nets and long lines were the most common gear operated and the catch-per-hour of these gears was 0·45 and 0·19 kgm. respectively.

Catch Statistics of Godavary River at Rajahmundry

A stretch of 60 miles of the Godavary was studied and the fish catch (from March 1959 to February 1960) was estimated and tabulated on next page.

Biological Investigations

A total of 23481·43 kgm. of *M. aor* and 14040·02 kgm. of *M. seenghala* were estimated to have been landed during 1959–60 at Allahabad from Sadiapur and Daraganj Centres. 100 specimens of *M. aor* (T.L. 53–989 mm.) and 79 of *M. seenghala* (T.L. 59–1067 mm.) were studied in detail. Sexual maturity (season-wise) has been recorded. Between February and June various mature and just-spent specimens were recorded, indicating that the spawning

	Total (kgm.)	Per day (kgm.)
1959—		
March ..	21022·79	678·15
April ..	17338·13	577·93
May ..	15614·52	503·69
June ..	9759·06	325·30
July ..	6584·84	212·41
August ..	4885·85	157·60
September ..	13299·59	443·31
October ..	26283·19	847·84
Nobember ..	23286·36	776·21
December ..	17470·58	563·56
1960—		
January ..	10587·67	341·53
February ..	16725·40	576·73

season of both species could be placed between these months. The following gonadial characters were determined for *M. aor:*

Immature stage	.. 0·01–0·19 mm.	ova diameter
Intermediate stage	.. 0·02–0·42 mm.	do.
Maturing stage	.. 0·43–0·81 mm.	do.
Ripe	.. 0·81–1·20 mm.	do.

Spent ovary-flaccid with degenerate ova.

By studying seven pairs of gonads in *M. aor* and one pair in *M. seenghala*, fecundity noted was between 772 and 1,002 ova per gm. weight of ovary in the former and 975 in the latter. The following regressions have been calculated by the method of least squares:

(i) No. of ova spawned : T. L. of fish:

$$\text{Log } Y = -0{\cdot}95138 + 1{\cdot}99552 \text{ Log T.L.}$$

(ii) No. of ova spawned: Weight of fish.

$$\text{Log } Y = -1{\cdot}70610 + 0{\cdot}86492 \text{ Log weight.}$$

Gonado-somatic indices in *M. aor* for four years, from 1955 to 1959, show that the index value was the highest in April 1956, 1957 and 1958 and in March 1959. Values were the lowest between July and August, with a progressive development culminating in the highest values in March to April. Large number of early developmental stages of both the species (6 to 9 mm. and 13 to 18 mm. T.L.) have been procured in February and March from breeding pits (known as Thalas or 'kunda') at various shallow portions of the main river stream of both the Jumna and the Ganga. From the length-frequency studies and means calculated from examination of vertebral (centrum) rings, the following age-groups could be determined for *M. aor:*

Age	Length frequency mm. (T.L.)	Mean lengths calculated from vertebral rings mm. (T.L.)
1st Year ..	460	440
2nd Year ..	660	620
3rd Year ..	820	904
4th Year ..	900	910

Morphometric studies for analysis of co-variance between males and females were made on seven characters. The regression equations were calculated and appropriate 'F' tests revealed that except in dorsal and pectoral spines none of the characters were statistically significant between sexes.

Examinations of guts revealed that adults of both species subsist mainly on teleosts (33·81 and 60·63% respectively). Insects were found only in 7·24% of *M. aor* and were completely absent in *M. seenghala*. Crustaceans comprised 6·42% and 6·27% respectively. Juveniles of *M. aor* feed mainly on insects (54·55%), whereas those of *M. seenghala* consume mainly teleosts (61·74%).

Total landings of *Catla catla* in the Ganga and Jumna were 53780·03 and 95867·62 kgm. respectively. The fish was found to feed on 50·3% by volume of Crustacea, 7·4% algæ, 6·1% insects, 3·8% plants, 2·5% rotifers, 1·5% diatoms, 0·2% protozoa and 15·6% sand or mud. Gastro-somotic index was the lowest in June and highest in March. Gonads of IV, V and VI stages were noted in April, May, June and July, the species spawning by the commencement of monsoon. Number of mature ova per

unit gram weight is 210. Scale readings of growth checks (in rings) were made and the following tentative conclusions have been arrived at:

Age	Size range (mm.)	Mean length (mm.)
End of 1st Year ..	175–245	210
End of 2nd Year ..	422–492	457
End of 3rd Year ..	598–669	633
End of 4th Year ..	774–845	809
End of 5th Year ..	951–···	951

24846·48 and 155561·32 kgm. of *Silonia silondia* were landed from the Ganga and Jumna respectively, forming 2·76% and 2·85% of the total yield. Gut content analyses showed that fish formed 32·33%, insects 29·08%, prawns 3·72%, plant matter 5·6%, digested organic matter 15·87%, snails 0·12%, conchostracans 1·45% and fungi 0·26%.

Gonads of VI stage were noted in August and May with spent specimens occurring in May, October, November and December. Number of mature eggs per unit gram weight is 28.

3,570 kgm. (valued at Rs. 3,590) of *Rita pavimentata* were estimated to have been landed at Hoshangabad (Sahagunj) centre from the Narbada river. Size-group 125 to 205 mm. was the most dominant (60·8%) in the year. Catch-per-unit-effort of 500 hooks per hour was 0·12 kgm. (range 0·05 (in July) to 0·19 kgm. (in August). Baits used were dragon-fly nymphs, prawns, earthworms, fish flour, bivalves and gastropod flesh. Sex ratio was 36·4 (M): 63·6 (F).

Data obtained from analyses of stomach contents are given below:

	Average food (c.c.)	Gastro-somatic index	Condition of stomach %	Condition of factor
April–May ..	0·36	1·05	19·1	1·335
June–July ..	1·16	2·19	39·2	1·435
August–September ..	0·60	1·75	7·3	1·425
October–November ..	0·30	1·19	5·9	1·424
December–January ..	0·20	1·10	5·9	1·395
February–March ..	0·11	1·00	0·0	1·355

Main food items were molluscs 38·0%, prawns 6·6%, macrovegetation 5·5%, insects 4·5%, teleosts 3·4%, earthworm 0·7%, centipedes 0·3% and microvegetation 0·2%.

2,704 specimens were measured for length-frequency studies and the following modal characters were noticed:

Age (year)	Mean length (mm.)
I	153
II	213
III	258
IV	288
V	301

Cleithrum bones from 357 specimens were studied and results indicate that the markings are probably annular.

Gross examination of gonads, ova diameters and gonado-somatic index has clearly shown that the fish spawns from July to September, maturity being attained between 213 and 268 mm. Fecundity ranged between 3,000 and 25,000 ova, among 240 to 250 mm. sized fishes.

Exploitation of Fish-Seed Resources

Spawning grounds of *Hilsa ilisha* in the Narbada river were located between Poicha and Indravarna (18 miles) but spawn was available only at Poicha. Collections of Mahseer fry in the same river during five months (November to March) were successful. Spawning of this fish occurs twice, first during monsoon and later in winter. The species is already being stocked on a large scale by the M.P. Fisheries Department from fry obtained at various places.

Systematic operation of shooting nets in the Godavari at Rajahmundry and experimental rearing of spawn from July to end of September gave the following results regarding density of carp spawn resources in Godavari river:

Species	% in total	% among major carps
Labeo fimbriatus ..	23·8	59·9
Catla catla ..	6·3	19·4
Cirrhina mrigala ..	5·2	19·1
Labeo calbasu ..	0·3	0·9
L. rohita ..	0·2	0·7

In order to ascertain whether the Tilaiya and the Konar reservoirs of the Damodar Valley Corporation could be self-sufficient in their fish-seed resources, investigations were undertaken during August 1959. Major carps already introduced do actually spawn in the connecting rivers above at the first and to a small extent during subsequent flooding, but the eggs and hatchlings seem to perish and fail to attain even fry sizes.

Physico-chemical and Biological Factors Affecting the Distribution of the Ganga Fisheries

Analysis of regular collections made from seven centres (*viz.*, Kanpur, Allahabad, Varanasi, Ballia, Patna, Bhagalpur and Rajmahal) on a 700-mile stretch of the Ganga river showed that during the last quarter free CO_2 registered a gradual decline, while dissolved oxygen attained a maximum of 11·4 p.p.m. in January and pH remained steady (8·2). Inorganic nutrients (nitrates, phosphates and silicates) are fairly well represented. Lower reaches seem to have less nutrients than the upper. There has been a rise in plankton with temperature. *Mougeotia*, *Spirogyra* and *Synedra* spp. amongst phytoplankters and *Keratella*, *Brachionus* amongst zooplankters were the more important organisms. Since the middle of February, *Actinastrum*, *Anabæna*, *Eudorina*, etc., have tended to increase in number. Bottom biota also showed an increasing trend with rise in temperature. Chironomids (105 per sq. foot), insects, molluscs and vermes dominated. Varanasi indicated the richest biota. Stomachs of about 400 fish from the above centres were examined. Generally insect debris were found to be the dominant items, followed by fish remains.

Stream Pollution Studies

None of the chemical conditions observed in Ganga was sufficient to cause mortality of fish, as both dissolved oxygen and B.O.D. (except close

to the Jajmau outfall), even though low, were unable to cause destruction of fish. No planktonic organisms except amæboid protozoa, fungal spores and hyphæ and *Oscillatoria* and sewage matter are added to the already organically-rich Ganga water. No anaerobic or toxic conditions are allowed to develop in the sewage because of its lead into the river from domestic or factory sources.

Blooms of *Mougeotia* and *Fragillaria* and at one station swarms of *Cladocera* were noted in April and May. These had no relation to pollution. Colonies of Tubificid worms and Chironomids were the major bottom organisms, indicating pollution of the surface water below Jajmau outfall for about a mile. The polluted water on the right bank was still inhabited by fishes like *Labeo dero*, *L. bata*, *Rohtee* spp. and other medium-sized carps, indicating that no adverse effects were being felt by them. *Mystus* spp., *Eutropiichthys vacha* and *Clupisoma garua* were present within the polluted portion.

Lethal limits of tolerance shown by *Mystus vittatus* and *Puntius sophore* were studied with reference to textile (three phases) and tannery wastes (three kinds). Results obtained are as follows:

Nature of liquor	Toxic range	Test fish	Average size	Average weight
Chrome tan ..	6·03– 8·14	*P. sophore*	71·53	5·73
Sulphide tan ..	9·45–10·98	do.	66·16	4·78
Vegetable tan ..	6·03– 8·14	do.	72·51	4·66
Chrome tan ..	10·98–12·76	*M. vittatus*	73·64	4·04
Sulphide tan ..	do.	do.	73·83	3·98
Vegetable tan ..	6·03– 8·14	do.	74·90	4·62
Kier liquor ..	4·47– 6·03	*P. sophore*	69·96	5·00
Dye liquor ..	10·98–14·82	do.	68·80	5·31
Bleach liquor ..	0·5– 0·10	do.	74·10	6·21
Do. ..	0·1 – 0·15	*M. vittatus*	75·80	4·91

No significant changes in tolerance are exhibited by the fishes from season to season. Chromium as hexavalent indicated a dilution tolerance

range of 150 to 220 and 340 to 410 p.p.m. by *M. vittatus* and *P. sophore* respectively.

All three tannery liquors, three phases of textile wastes and raw sewage were analysed for 19 to 20 characters. Tannery liquors contain readily and highly oxidisable organic suspensions than textile liquors with 510 to 1,460 p.p.m. (3 mts. permanganate) values as against a maximum of 590 p.p.m. in textile wastes. Dye and vegetable tan liquors have a very high B.O.D. of 7,272 and 4,800 p.p.m. respectively, which at once reduce oxygen to nil, if sufficient dilution is not available. Sulphide values are high. Bleach liquor showed a value of 141 p.p.m. of free chlorine. No chromium was found in resultant final liquors as a result of its precipitation. Raw sewage at the outfall has a pH of 6·8 with a B.O.D. of 310 and a chloride content of 100. Nitrates and phosphates were 6·67 and 3·3 p.p.m. respectively.

From September 1959 ecological studies on the small stream Daha in the Savan Subdivision of Saran district (N. Bihar) were undertaken. A stretch of 20 miles of the river was studied each month from six stations.

It was possible to observe fish mortality twice in the river during September and November, when except for air breathing Murrels and cat-fishes, all other fish died, rendering the entire river barren for 15 miles. Fish supply to the stream is renewed regularly from the Goghra below. Fingerlings of *Cirrhina mrigala* and *Labeo rohita* were prominent amongst the major carps. Plankton life is very rich except close to the outfalls where the complex "sewage fungi" colonise along with blankets of Chironomids and Tubificidæ. Molluscs are scarce and are generally found dead after each mixing of distillation wastes. Mortality of fish in the Daha are entirely due to deoxygenation by changes brought by breaking up of sulphates to H_2S, which under low pH condition prove lethal. Ferric salts in the process of conversion into ferrous and *vice versa*, seem further to contribute to thorough deoxygenation.

Bioassay experiments using *Puntius sophore* indicated that distillary effluents have toxic range between 6·03 and 8·14% when fish are 78·8 mm. (average T.L.) and 9·23 gm. (average weight). Raw undiluted sugar wastes did not show any toxicity even after 24 hrs. Complications arise only when these sugar wastes are subjected to bacterial activity. Distillery wastes contain highly oxidisable substances and showed a B.O.D. of 8,750 p.p.m. and O.C. value of 1,754 p.p.m. (3 mts. KM No. 4). Sugar wastes showed a B.O.D. of 820 p.p.m. and O.C. value of 65 p.p.m. Sulphur-reducing bacteria favoured in these two effluents produce H_2S (as much as 12 p.p.m.) and prove lethal to fish.

Lacustrine Investigations

Investigations at Tungabhadra Dam

Data collected from the Hospet Fish market indicate that 20·108 m. tons of fish were brought to the market during the year. Carps formed over 50% of the catches during April and August to January. Since the nets used are very selective, significant variations in sizes are not obtained. The total weight, size range and mean size of the twelve predominant species were calculated as shown below:

	Weight (kgm.)	Size range (mm.)	Mean size (mm.)
Barbus kolus ..	5694·0	200–460	315·8
B. pinnauratus ..	300·4	180–340	253·6
B. tor ..	309·16	200– 680	436·8
B. dobsoni ..	655·77	221– 720	358·6
Labeo fimbriatus ..	2798·7	201– 820	473·4
L. potail ..	177·1	220- 580	306·8
L. calbasu ..	370·1	220– 640	388·5
Mystus aor ..	4330·2	220– 880	531·0
M. seenghala ..	5254·0	200–1100	702·0
Silonia silondia ..	387·0	180–560	362·3
Wallago attu ..	505·0	280–1020	662·0
Bagarius bagarius ..	488·1	301– 840	572·3

Departmental fishing was undertaken in the reservoir on 147 days by using Uduvalai and Rangoon nets. The average catch per day was 4·52 kgm. *Barbus kolus* predominated in the catches this year also, followed by *Mystus seenghala*. *B. kolus* (34·6%), *M. seenghala* (25·1%), *L. calbasu* (10·4%), *L. fimbriatus* (6·5%), *M. aor* (6·5%) and *S. silondia* (3·2%) were the important fishes represented in the catches. The catch-per-day in kgm. for Uduvalai and Rangoon nets worked out to as in next page.

Mesh ..	0·5″	1·0″	1·5″	2″	3″
Uduvalai—					
Catch per day	0·48	0·167	1·6	1·8	0·35
Mesh ..	0·5″	1·0″	2·5″	3·5″	..
Rangoon nets—					
Catch per day	0·225	0·2	0·34	0·30	..

It was observed that Uduvalai nets yield more catches than Rangoon nets because the bottom-feeding fishes (*Barbus* spp.) form the important group of fishes in the area.

A survey of the nets and tackle used by fishermen were undertaken during the year under report. Drag nets with stakes are used during the monsoon months near the margin for catching minnows. Larger drag nets are used at Hampasagaram during May, when the water level goes down. Long lines are used by fishermen throughout the year. Main fishing gear is Uduvalai, 100 to 200 yards long, 1″ to 3″ mesh and about a metre in height. Local fishermen do not use Rangoon nets. The catch per unit of effort for the tackles worked out to:

Drag net—4·3 kgm. per hour.

Uduvalai net—0·28 kgm. per 100 yds. per 12 hours in monsoon, 0·21 kgm. in post-monsoon and 1·9 kgm. in winter months.

Hook and line and long line—0·25 kgm. per 1,000 hooks per hour.

Over 2·0 lakhs of fingerlings of Catla, Rohu and Mrigal have been released in the reservoir during December 1959.

Biological studies on the more important species of fish were continued. Fecundity studies on 17 species are being made.

Plankton studies were regular and it was seen that generally zooplankton was predominant. There was a peak of phytoplankton in July to August due to blue-green and green algæ and a second peak during January to February due to diatoms. In zooplankton, copepods, rotifers and cladocerans and in phytoplankton, *Nitzschia*, *Merismopedia* and *Pediastrum* were the important constituents.

Surface water temperature varied between 22·9° C. and 31·3° C., with maxima in May and September. Two minimum values were obtained, one in July and the other in January. pH varied between 7·5 and 8·4. Turbidity was maximum in July (Sechi disc reading 15·8 cm.) and minimum in February (233·68 cm.). Dissolved oxygen showed two maxima, in August and January, and two minima, in April and October. During April to May the difference

in oxygen values at surface and bottom was 2·7 mg./e. and during other months the same was between 0·3 to 0·6 mg./e. Carbonates were in very low concentration between July and December 1959. The maximum amount of bicarbonates was found in June (101·3 mg./1.). Maximum phosphate was found in March (0·113 mg./1.) and minimum in October (0·024 mg./1.). Nitrates were in traces during June and 0·153 mg./1. in November. The increase in nitrate and phosphate concentration took place after the entry of the flood waters in the reservoir during July. Oxidisable organic matter in surface waters was 0·025 mg./1. in April, 0·0[illegible] mg./l. in August and 0·052 mg. during September to March.

To assess the production of organic matter and rate of photosynthesis at different depths, a series of experiments was conducted and it was found that at 2 metre depth, there was maximum photosynthesis, while below 8 metres it was negligible. The average figures of glucose production in mg. per cm. for the top 8-metre-layer were as follows:

November, 76·0; December, 46·9; January, 58·9; February, 71·96; and March, 89·98.

A direct relationship between the production values and concentration of phytoplankton has been observed. Soil analysis of bottom mud of the reservoir were made during three months with the following results:

	October 1959	January 1960	February 1960
Organic carbon ..	0·246	0·268	0·202
Total nitrogen ..	0·068	0·042	0·058
Calcium carbonate ..	4·2	4·1	3·9

Bottom fauna studies indicated that Gastropoda are more up to 15 meter depths and bivalves decrease in number with increase of depth. Oligochætes predominate between 21 to 25 metre depths and Ephemeroptera are found in shallower regions (upto 10 metres). Dipteran larvae are more between 6·10 metres than between 16–20 metres depths, but again increase between 21 and 25 metres. Ostracoda predominate at 11 to 15 metre depths.

Rapid survey of Collair Lake

The Fisheries of Collair lake was surveyed during the year under report. There are about 5,200 fishermen having 2,500 dug-out boats. The fishing

in the main lake region is conducted by rectangular basket traps, fixed in two tiers in series over ½ mile long and called as "Dodakattu". Carps and cat-fishes form the main catches in these traps. In the Akhividu region on the river Uputeru stake-nets are used; 10 to 15 such nets are put in a series and the catches comprise mostly of estuarine forms like *Lates calcarifer*, *Sciæna* sp. and eels. During the summer months the main catches in the lake consist of air-breathing fish like *Saccobranchus* and *Anabas*.

Water samples from different regions of the lake were analysed and the results obtained are summarised below:

	Total alkalinity		Phosphate		Nitrate	
	June	November	June	November	June	November
Sriparu ..	148	168	0·08	0·148	Trace	0·08
Kaiklur ..	204	184	0·007	0·06	0·12	0·13
Akhividu	190	160	0·002	0·038	0·01	0·12

Studies at Krishnaraj Sagar

Analysis of data obtained from the catches of the lake area showed that *Barbus carnaticus* (275 to 468 mm.) formed nearly 25% of the catches. Mature males were found in June and mature females in July. *Barbus dubius* (303 to 760 mm.) formed nearly 15% of the catches, with mature males in July and October. *Barbus micropagon*, *Labeo kontius* and *Labeo fimbriatus* come next in order of importance. Amongst cat-fishes *Wallago attu* is more common. The chemical conditions of the water was found to be as follows:

	P.H.	Turbidity	Alkalinity	Phosphate (mg./l.)	Nitrate (mg./l.)	Iron (mg./l.)
June ..	8·2	24″	120	0·1	0·12	..
July ..	7·5	13″	22	0·09	0·16	2·03
October ..	8·0	..	65	0·045	0·14	0·08
December ..	8·3	..	97	0·026	0·14	0·08

Estuarine Division

Investigations on the Fisheries of the Hooghly, Matlah and Mahanadi Estuaries

The year under report envisaged the commencement of the second phase of this programme of investigations. During the first phase, data were collected on all the species of fish and prawns caught in the estuaries, which yielded information on various aspects of fishery biology. In the second phase, 26 species of fishes and 5 of prawns, each of which forms not less than 1% of the total landings of the estuary, were selected for more intensive studies of population dynamics.

With a view to estimate the sampling error and assess the suitability of the design now followed for the collection of catch statistics, a pilot survey was conducted in Zone II of the Hooghly. Interpenetrating sampling technique was adopted in six selected villages, one enumerator sampling three villages. The monthly coefficient of variation was found to be 3·5% during the period of survey. However, during the period of sampling all the types of gear normally operated were not represented. Since there is an appreciable variation in the types of gear operated in each centre from time to time, it is proposed to increase the number of sampling centres in each zone to four and reduce the period of sampling to two days.

After an initial survey of the dry and fresh fish markets in the Mahanadi estuary area, a new market sampling procedure was designed for the estimation of total catch. For the assessment of catch-per-unit-of-effort, the entire estuary north of Devi River has been divided into seven zones where sampling survey is being carried out fortnightly.

There was a marked increase in total landings of fish in the Hooghly and Matlah estuaries as compared to the previous year, which was due mainly to increased catches in the lower Sunderbans and Zones III and IV (Rupnarain) of the Hooghly. Catches in Zones I and II of the Hooghly and the upper reaches of Matlah were however poorer than during last year. Moderate success was achieved by the bag net fishermen during the winter months in the lower Sunderbans.

The combination of sampling survey and total enumeration methods was continued to estimate the total catch and catch-per-unit-of-effort in the estuaries. The data for Hooghly and Matlah are summarised below.

Zone-wise total catch figures of Hooghly and Matlah estuaries.

	Zone	Weight in metric tons
Hooghly ..	I	465·3
Do. ..	II	103·0
Do. ..	III	1940·6
Do. ..	IV (Rupnarain)	349·7
Matlah ..	V	102·5
Lower Sunderbans		1177·5
	TOTAL ..	4138·6

Analysis of Commercial Catches

During the year under report, the failure of Hilsa fishery brought down the percentage composition of clupeoids group in the total landings to nearly 8·4%. Details regarding *Hilsa ilisha* which is the most important species in this group are given elsewhere. Among the other clupeoids only *Setipinna taty*, *S. phasa*, *Coilia borneensis*, *C. ramcarati* and *Ilisha elongata* contribute significantly to the fishery and these were studied in detail.

Setipinna phasa afforded a fishery of some importance in the estuaries. Juveniles (modal length 75 mm.) were predominant in the catches of the Rupnarain and the middle and upper zones of the Hooghly during March to July. From August onwards, maturing fishes started appearing in the catches mainly from the upper zone of the Hooghly and in lesser numbers from the Matlah. August to October were lean months and from November to February both uveniles and maturing adults (ranging from 20 to 270 mm.) were represented in the catches from all the zones of the Hooghly (mainly from the upper zone), whereas juveniles continued to contribute to the catches from Rupnarain. The fish was not caught from the Matlah estuary till July when juveniles (modal length 65 mm.) started appearing. Bigger size-groups of maturing individuals entered the fishery in October and persisted throughout the winter months.

Annual catch-per-unit-of-effort figures (in kgm.) March 1959 to February 1960

	Hooghly			Rupnarain	Matlah
	Zone I	Zone II	Zone III	Zone IV	Zone I
Bagnets :					
Standard unit (800–1000)	4·23	2·41	178·0	6·08	13·09
Drift nets:					
Kona ..	0·89	..	..	..	..
Ghai kona ..	3·13	..	..	..	..
Chandi ..	..	0·87	..	2·26	..
Lift nets: ..					
N. vashali ..	2·83	0·52	..	..	..
Scitki ..	0·92	2·07	..	..	..
Purse nets:					
Sanglow ..	0·30	0·44	..	..	..
Cast nets:					
Vachari ..	2·09	..	16·8	..	
Khepla ..	1·26	..		..	..
Trawl nets: ..					
Moi ..	2·15	2·67	..	..	..
Buro ..	1·23	..	..	..	..
Tangle nets:					
Janglo ..	7·38	..	..	..	..
Seine nets:					
Ber ..	..	..	30·4	..	7·26
Berpata ..	..	..	58·7	8·86	..
Chatber ..	9·28	..	..	..	..
Khalpata ..	..	..	38·0	..	6·61
Khani ..	..	..	..	..	5·38
Dhali ..	1·40		..	..	..
Pata ..	1·19	..	..	..	..
Kochal ..	7·73	..	..	..	..
Hooks and line:					
(100 units) ..	0·31	0·38	8·0	1·82	1·11
Traps ..	0·14	..	..	..	..

S. taty contributed more to the catches of the estuaries than even Hilsa this year, accounting for nearly 2·8% of the total landings. Its fishery,

however, was restricted mainly to the lower zone of the Hooghly and Matlah. Small quantities of immature and maturing individuals were landed from the lower zone of the Hooghly, Matlah and Rupnarain during March to October. The fishery increased in magnitude in winter months particularly in the lower zone of the Hooghly, where fishes with a modal length of 85 mm. constituted the catches. Maturing, mature and partly spent individuals also were landed from this region.

Of the two selected species of Coilia, *C. borneensis* was more abundant in Rupnarain and middle zone of the Hooghly estuary, whereas *C. ramcarati* was represented mainly in the catches from lower Sunderbans and lower zone of the Hooghly. Juveniles of *C. borneensis*, (41 to 70 mm.), predominated in the catches from January to April and November and December. Maturing adults (80 to 142 mm.) were caught during the period April to June from the middle zone of the Hooghly, Matlah and Rupnarain, where they appear to spawn. *C. ramcarati* was landed in good quantities from lower Sunderbans during winter months, when three different size-groups (modal lengths 75, 120 and 165 mm.) constituted the fishery. New recruits having a modal length of 53 mm. entered the fishery in January and February. The fish appears to spawn during December to February. Juveniles of *Ilisha elongata* ranging from 31 to 55 mm. were landed from all the zones of the estuary during almost all the months of the year.

Perches contributed to nearly 1·5% of the total landings of the Hooghly estuarine system, with *Sillago panijius* and *Lates calcarifer* being the more important species. *Lates calcarifer* caught in the estuaries ranged between 12·0 and 88·2 cm. in length, the dominant size-group being the younger ones measuring 14 to 20 cm. The fish was caught in greater abundance from Matlah and Ichamati and was rare in the Hooghly. *Sillago panijius* was represented in the catches of the Hooghly and Matlah almost throughout the year by three distinct size-groups with modes at about 35, 125 and 205 mm. of which the second size-group was predominant. Generally maturing and mature adults were caught in the lower reaches of the estuary, whereas the younger size-groups were more abundant in the other zones.

Of the four species of mullets that contribute to the fishery, *Mugil tade* and *M. parsia* were found to constitute a predominant part and hence were selected for detailed studies. Mullet landings accounted for a little over 1% of the total catches of the estuary. *Mugil corsula* was caught throughout the estuary and was represented in the upper and middle zones by ' 0 ' group individuals and in the lower zone by maturing and mature I and II year groups.

M. tade was represented in the lower Sunderbans by three distinct size-groups, having modal lengths of 68, 125 and 300 mm.

Cat-fishes formed a very important group accounting for nearly 6% of the total landings. *Tachysurus jella*, *Pangasius pangasius*, *Osteogeneiosus militaris* and *Plotosus canius* were found to contribute significantly to the fishery and hence were studied in detail.

I and II year class *T. jella* (modal lengths 115 mm. and 205 mm.) were landed from the middle zone and Rupnarain during February to July. In the later months, *i.e.*, August to January, the landings of the species were confined to the lower zone of the Hooghly, lower Sunderbans and Ichamati, where in addition to the above age groups, bigger fish ranging between 500 to 830 mm. were caught. During winter months fishes of larger size-groups were abundant in the catches. Individuals in the IV stage of maturity were obtained from Rupnarain and Middle zone of Hooghly during April and May.

Pangasius pangasius was represented in the catches of the upper and middle zones of the Hooghly, Rupnarain and Ichamati from February to July. During February to April, only I year class (110 mm.) constituted the fishery and during May to July, II year class (225 mm.) also were represented. From August to January the fishery extended to the lower zone also, where two additional age groups (*i.e.*, III and IV) were present. During winter mainly bigger size-groups, ranging from 500 to 960 mm. were landed from lower Sunderbans. New recruits (early 0 group, modal length 45 mm.) entered the fishery in large numbers during August to November in the upper and middle zones of the Hooghly and Rupnarain, and '0' and I year classes were caught in Matlah in small numbers during most of the months.

The catches of *O. militaris* were confined to the middle zone of the Hooghly and Rupnarain during March to August where I, II and III year classes, having modal lengths 145, 225 and 335 mm. respectively, constituted the fishery, the II year class being predominant. During November to February the fishery shifted to the lower zone where, in addition to the above age groups, '0' year class (75 mm.) was also present. All individuals belonging to II and III year classes were found to be in an advanced stage of maturity during the months April to June, when they appear to congregate in the middle zone of the Hooghly and Rupnarain for spawning. Capture of adult males with eggs in the buccal cavity confirmed the above conclusion.

P. canius was caught mainly in the Ichamati estuary throughout the year and stray specimens were obtained in the lower zone of the Hooghly

during May, August and December. In the Ichamati one size-group (modal length 115 mm.) only constituted the fishery during February to July, but in August three more size-groups (modal lengths 295·5, 375·5 and 655·5 respectively) entered the fishery. However, the bigger size-groups occurred only for a short period and from October onwards only the first three groups persisted till February.

Harpodon nehereus formed an important constituent of the fishery in the Hooghly, Matlah and Rupnarain, accounting for nearly 28% of the total landings. Immature size-groups, ranging from 60 to 90 mm. were caught almost all the year round from the middle zone of the Hooghly, Rupnarain and Matlah. During winter months appreciable quantities of this fish were landed in the lower zone of the Hooghly. These catches comprised of four size-groups, having modal lengths of 163, 203, 258 and 305 mm. respectively. Mature and spent individuals measuring over 132 mm. were captured from the mouth of the estuary only during the winter months. Fresh recruits (modal size 45 mm.) entered the fishery during February to April mainly in the lower zone of the Hooghly.

Sciænids constituted nearly 2·6% of the total landings. Of the ten species caught in the estuaries, only *Pama pama*, *Sciæna biaurtus* and *S. miles* were landed in any appreciable quantities. *P. pama* was the most important species and during March to May, three size-groups of this species, having modal lengths of 25, 125 and 205 mm., comprised the catches mainly from the upper and middle zones of the Hooghly and the Rupnarain. From June onwards the species started appearing in the catches of the lower zone also. An additional size-group, having a modal length of 345 mm., entered the fishery in September and continued to occur for the rest of the year. In general, bigger size-groups only were landed from the lower zone of the estuary, whereas all the size-groups were represented in the other zones. '0' group individuals dominated the fishery in the earlier months, whereas the 205 mm. size-group was predominant during the winter months. Fresh recruits having a modal size of 25 mm. entered the fishery during all the months of the year except August to October. Individuals with gonads in an advanced stage of maturity and also spent ones were obtained from the upper and middle zones of Hooghly and Rupnarain during January, February and June to August, indicating thereby that the fish spawns in these zones. *Sciæna biauratus* and *S. miles* were landed mainly from the lower Sunderbans during winter months.

Among threadfins, which accounted for 2·9% of the total landings, only *Polynemus paradiseus* and *E. tetradactylum* constituted a significant propor-

tion. Juveniles of *E. tetradactylum* (2·5 to 15·5 cm.) were represented in the catches of the Matlah throughout the year, whereas in the Hooghly three distinct size-groups having modes at 23·6, 30·6 and 41·6 cm. contributed to the fishery of the lower zone and lower Sunderbans during December to February, the smaller size groups being predominant. In the upper and middle zones and the Rupnarain, stray specimens of '0' group were caught. *P. paradiseus* belonging to 0, II and III year classes (modal length 6·2; 11·5; 16·2 and 21·5 cm. respectively), of which I and II year classes predominated, were landed in large quantities in lower Sunderbans and lower zone of the Hooghly during January to March. All these size-groups constituted the fishery of the rest of the zones of the Hooghly during April to August. Mature adults were present in the catches from the middle and upper zones of the Hooghly and Rupnarain during April and May. New recruits (modal length 4·7 cm.) entered the fishery and formed the predominant group from June to August.

Trichiurus savala and *T. haumela* formed the important species of ribbon fishes which constituted nearly 13·4% of the total landings. The catches of these species were confined to the lower zone of the Hooghly and other areas of lower Sunderbans from November to February. Maturing individuals of *T. savala*, ranging in length from 21·6 to 42·6 cm., formed the fishery in Hooghly, whereas immature and maturing fish ranging between 18·5 and 29·5 cm. were caught in the Matlah. Immature and maturing *T. haumela* ranging from 18·6 to 36·4 cm., of which the bigger size-groups were predominant, were landed from the lower zone of the Hooghly and lower Sunderbans only.

Among the five species of prawns selected for detailed studies, *Palæmon mirabilis*, *Leander styliferus* and *Metapenæus brevicornis* were landed in appreciable numbers. *P. mirabilis* was caught mainly from the Rupnarain and upper and middle zones of the Hooghly, during all the months of the year, except September and October. Smaller size-groups (11 to 35 mm.) dominated the catches during November to February, while bigger size-groups (16 to 50 mm.) were present during other periods. The species appeared to mature when it attained a length of 30–38 mm. Berried individuals were obtained from the catches in the Hooghly and the Rupnarain river throughout the year. *Leander styliferus* was represented mainly from the catches of Matlah and lower zone of the Hooghly estuary by four size-groups. Size-groups having modal lengths of 43 and 78 mm. were landed during January to June. New recruits (modal length 18 mm.) entered the fishery in July and continued till November. A fourth size-group of adults (modal length

92 mm.) entered the fishery during November to December. Berried females (modal lengths 78 and 92 mm.) were caught in the lower zone of the Hooghly during November to February.

M. brevicorinis occurred mainly in the middle and lower zones of the Hooghly, Rupnarain and Matlah estuaries, majority of the catches being from the Matlah. Two size-groups having modal lengths of 33 and 67 mm. were represented during August to February. During the winter months, however, size groups ranging from 70 to 115 mm. were caught in large numbers from lower Sunderbans. No mature females have so far been obtained. *P. carcinus* ranging between 46 and 210 mm. occurred in the upper and middle zones during July to November and in the lower zone of the Hooghly from December to March. Females with maturing ovaries were caught both from Kolaghat and Fuleswar area, during December to February. *P. malcomsonii* ranging from 21 to 135 mm. occurred in the catches of the middle zone of the Hooghly and the Rupnarain. Berried individuals of the species were caught from May to July in the middle zone, which appears to be the spawning ground of the species.

Fishing in the Mahanadi estuary was restricted largely to the lower reaches. There was a significant decrease in the fishing 'effort' in the Hukitola lake area because of the restrictions enforced on non-indigenous fishermen. Hilsa fishing of some magnitude was conducted in this area after a lapse of four years. Other important species that constituted the fisheries were *Mugil cephalus*, *M. troscheli*, *Polydactylus indicus*, *Eleutheronema tetradactylum*, *Sciœna* spp., *Setipinna phasa* and *Lates calcarifer*. *M. cephalus*, ranging from 21 to 39·6 cm. in length, were landed from the lower reaches of the estuary, the dominant size-group being between 25 and 33 cm. The majority *M. troscheli* landed were from the neighbourhood of Paradeep, Karnasi and Jatadharmohan and ranged from 19 to 48·9 cm. *Setipinna phasa*, which ranged in size between 15 and 20 cm. with a modal length of 17·5 cm., formed significant part of the catches in all the areas. *P. indicus* ranging in length from 12·7 to 89·0 cm. were caught in the lower reaches, the dominant size-group having a modal length of 38 cm.

Hydrobiological Observations

Surface temperature and salinity ranges in all the estuaries under observation were significantly lower this year than during previous year. Surface temperature in the Hooghly ranged from 20·4° to 30·87° C. and in Rupnarain and Matlah from 19·2 to 31·1 and 20·72 to 30·77° C. respectively. The Hooghly estuary extending from Fraserganj to Medgachi could be divided into three zones on the basis of salinity: (1) an upper zone (between

Khusigoli and Medgachi) which had only traces of salinity during all the months of the year (except May and June when maximum salinity reached 0·6‰); (2) a middle zone (comprising the area between Khusigoli and Diamond Harbour) where the salinity ranged between traces and 19·78‰ and (3) a lower zone (the area between Frasergunj and Diamond Harbour) where the salinity ranged between 9·48 and 32·11‰. In the Matlah and Rupnarain the ranges were from 4·49 to 27·52‰ and traces to 16·00‰ respectively.

The general decline observed in the production of both zoo- and phytoplankton during the previous year continued except for occasional spurts of increase at a few isolated centres. During the pre-monsoon months (April to June) production of zoo-plankton was uniformly low in all the zones, mainly due to decrease in rotifers and cladocerans in the upper zone and copepods in the lower and middle zones. An increase was registered during the monsoon months in Rupnarain, Matlah and lower zone of the Hooghly. An increase in phytoplankton was observed in the upper and lower zones during the pre-monsoon months. This was followed by a gradual decline from June onwards in all the centres and was attributable mainly to failure of diatom crop. During the post-monsoon months a slight but significant increase was noticeable in the lower zone and Rupnarain. Freshwater and marine forms predominated in the upper and lower zones respectively, whereas both freshwater and marine forms were present in the middle zone.

Coscinodiscus, *Melosira*, *Synedra*, *Spirogyra*, *Pediastrum* and *Eudorina* were the more important phytoplankters, and copepods and rotifers were more dominant in zooplankton from the upper zone. In the lower zone, brackishwater copepods like *Paracalanus* spp., *Pseudodiaptomus* spp., *Acartiella* spp. and marine diatoms such as *Coscinodiscus*, *Biddulphia*, *Lithodesmium*, *Chætoceros*, etc. and algæ, like Trichodesmium, were predominant.

Larval and Young Fish Surveys

It was observed that larvæ of various species were generally more abundant in the Rupnarain as compared to other centres. Larvae and post-larvae of *P. pama*, *E. tetradactylum*, *Mugil* spp. and *Coilia* spp., ranging between 5 and 8 mm., were collected from Rupnarain, Matlah and the middle zone of the Hooghly during June to August. Larvæ of *Mugil* spp. and *P. pama* were obtained from lower and upper zones of the Hooghly also during August and September. Post larvae of *P. paradiseus* measuring about 8 mm. were represented only in collections from the Matlah during July.

Larvae and post-larvae of *S. phasa* were collected from the Hooghly and Matlah and those of *Anchoviella* sp. from lower zone of the Hooghly and the Rupnarain during June to September. Larvae of other sciænids and perches were present mainly in Rupnarain during June to September.

In the Mahanadi estuary, young ones of *Chanos chanos*, *Lates calcarifer*, *Anchoviella* spp. and other clupeoids and prawns were abundant in Ostar and Narayanpur centres during May and June, whereas larvae were scarce in Jamboo area. During July, August and September, larvae and young fish were rare in all the three centres.

Studies on the Culture of Brackishwater Fishes

The brackishwater fish culture unit commenced its work at the Kiragachamadeli fish farm belonging to the Orissa Fisheries Department. As a result of intensive survey it has been possible to locate mullet-seed collection centres near the farm site. Surveys to locate suitable collection centres for young of prawns suitable for cultivation are in progress. Experiments on the comparative merits of transporting conditioned and 'unconditioned' fry indicated that unconditioned fry stand transportation better.

After removing extraneous fishes and undesirable fauna, the ponds at the fish farm were stocked with mullet fry at the rate of 1000 per acre. Observations were made at regular intervals to assess their growth and survival. Observations on the soil nutrients, algal production and other hydrological features of the ponds were also made. To explore the possibilities of increasing production of benthic algæ and thereby fish production in ponds, experiments with chemical fertilizers and green manure were initiated. Four tanks are being manured with NPK in the ratio of 1 : 1 : 0·6 and two with semi-decomposed mangrove leaves at 2,000 lb./acre. A sudden increase in nitrogen was observed in the soil phase subsequent to fertilization. No such increase was discernible in the case of phosphorus, and this difference may be attributable to the fact that ammonium sulphate, unlike superphosphate, dissolves in water immediately.

A new set of pot culture experiments to study the major factors governing the growth and multiplication of benthic algæ in brackishwater ponds has been taken up. Experiments were conducted with salinities ranging from 0 to 30‰, and it appears that 15‰ salinity is the most favourable for the growth of *Oscillatoria* sp. Observations on the probable effects of salinity on the distribution of fertilizer elements on soil and water were also initiated. Experiments with ammonium sulphate indicated that in salinity ranges of 0 to 15‰ the presence of Na^+ ions does not significantly affect

the distribution of available nitrogen in soil and water. However, the possibility that in higher salinities the presence of excess Na + ions might effect the exchange of NH_4 + ion between soil and water, exists.

Investigations on the Hilsa Fisheries

The monsoon fisheries for Hilsa in all the major river systems were poor during the year. Slight improvement in catches was observed when there was good rainfall and consequent flooding of the rivers. The very heavy rainfall and extensive flooding in West Bengal late in the season did not help the upriver migration of Hilsa. The winter fishery for Hilsa in the West Bengal waters was also very poor. However, in the coastal areas adjacent to the lower Sunderbans, there were abundant catches of Hilsa in November to December, but this lasted for only about a fortnight. This is of special significance in view of a similar sporadic Hilsa fishery in the lower Sunderbans during the winter of 1958–59. Environmental studies indicate that turbidity and the quantity of plankton play an important part in the establishment of the Hilsa fishery in the lower Sunderbans. The late flooding of the rivers of West Bengal at the close of the monsoon season appears to have proved a handicap to the Hilsa fishery of the lower Sunderbans this year also.

The total Hilsa catch for the year in the area covered by the Hooghly, Rupnarain and Matlah river system including lower Sunderbans was approximately 139 Metric Tonnes. The zone wise landing figures for the period March 1959 to February 1960 are given below:

	kg.
Zone I	.. 26,464
Zone II	.. 5,368
Rupnarain	.. 28,783
Lower sunderbans	.. 78,097

The catch-per-unit-effort (in kg.) of the more important Hilsa nets in in the area is indicated below:

Name of net	Zone I	Zone II	Rupnarain
Konajal ..	0·89	..	..
Chandijal ..	..	0·87	2·26
Sanglojal ..	0·3	0·44	..

The total catch of Hilsa for the year from the Padma in the neighbourhood of Lalgola was 645·83 Metric Tonnes.

In the Godavari there was a Hilsa fishery of small magnitude during the monsoon season commencing in the later half of July. Below the anicut at Dowlaiswaram the catches were good during the last week of September. The fishery, however, declined rapidly and came to a close by the second fortnight of October. The winter fishery for Hilsa was extremely poor during the year. Moderately good catches were reported at Masakapalli during the last week of February. Juvenile Hilsa were caught in fairly good numbers in Jaruguvala and Gaminivala at Kotipalli during January to February.

The analyses of meristic and non-meristic characters of samples of Hilsa from the different river systems indicated that the stocks of all the major river systems sustain independent populations. The age structure of the populations are being analysed to ascertain whether significant differences in age structure are recognisable between populations.

The comparative study of fat content of Hilsa from different localities was continued and the results are summarised below:

Origin of samples		Average percentage of fat content
Sourashtra	..	16·73
Brahmaputra	..	7·15
Krishna	..	8·5
Godavari	..	2·5

The composition of the commercial catches of Hilsa from Padma, Ganga, Brahmaputra, Chilka Lake and the Sourashtra coast were studied in detail. The bulk of the catches in Padma, Ganga and Brahmaputra comprised of the $4\frac{1}{2}$-year age class. In Chilka lake 1 to 5 years' old Hilsa contributed to the fishery, the 2nd and 3 year groups forming the predominant age classes. The bulk of the catches of Hilsa on the Sourashtra coast appears to belong to the 5-year age class.

Efforts were made to tag as many Hilsa as possible during the year. Fish caught in Chandijal and other gill-nets were found unsuitable for tagging, while those caught in clap nets like the Sanglojal and its various modifications were the best suited. The total number of Hilsa tagged during the year was 578, of which 54 have been recovered in good condition. From observations made so far there appears to be great variations in the speed of movement of Hilsa. It also appears that the Hilsa shoals show a certain amount of dispersal in the area covered. The longest time interval between the release and recapture of tagged Hilsa has been $3\frac{1}{2}$ months.

Intensive propaganda among the fishermen and fish traders of Bengal, Bihar and Uttar Pradesh was carried out for increased return of recovered tags. A 16 mm. colour film on tagging of Hilsa has been prepared for the propaganda work.

Exploratory Fishing

Preliminary bottom contour surveys and exploratory fishing in the lower Sunderban areas with the Research and exploratory fishing vessel M. V. "Sunderbans" were started in December 1959 and continued upto February 1960. During the above period the vessel made 6 voyages covering the entire stretch of Sunderban waters, from the river Muriganga on the west to Haribhanga river on the east. Extensive operations were carried out in the river Muriganga, Saptamukhi and lower Matlah. The work done consisted mainly of bottom survey by echo-sounding, location of fishing grounds and experimental mechanised fishing.

Preliminary surveys showed that the average depth in the area varied between 5 and 8 fathoms and in most cases river-beds were very uneven and muddy. It was also seen that a few grounds suitable for trawling existed in rivers Muriganga near Frasergunj, Saptamukhi near Dwariknagar and east and west of Lothian Island, river Thakuran and in the lower reaches of river Matlah, where the river bottoms were fairly even and less muddy.

Fishing experiments were conducted mostly with trawl nets, although drift gill-nets and long lines were also tried. Results of trawling operations were satisfactory in the river Muriganga, Saptamukhi and lower Matlah. River Thakuran appeared to be very poor in fish stock. *Harpodon nehereus*, *Arius* spp., *Pangasius* sp., *Pama pama*, *S. biauritus*, *S. bruniuss*, *Parapenæopsis sculptilis* and *Leander styliferus* were the most important species collected and are mentioned here in the order of their abundance in the landings.

Chilka Lake Investigations

Tagging Operations in Chilka Lake

An intensive tagging programme of six commercially important fishes of the Chilka Lake was launched in September 1959 and the details of tagging operations conducted are summarised in the table below:

Name of fish	No. tagged during Sept.–Dec. 1959	Number recovered in					Total recoveries upto 31–3–1960	Overall percentage of recovery
		Nov. 1959	Dec. 1959	Jan. 1960	Feb. 1960	March 1960		
1 *Mugil cephalus*	2,355	59	75	47	12	5	198	8·41
2 *Liza troscheli*	2,873	7	95	55	8	12	177	6·16
3 *Eleutheronema tetradactylum*	544	11	20	8	4	..	43	7·90
4 *Lates calcarifer*	206	1	8	2	2	..	13	6·31
5 *Sparus sarba* ..	693	..	4	7	..	3	14	2·02
6 *Pseudosciæna albida*	43	..	..	..	..	..	..	..
TOTAL ..	6,714	78	202	119	26	20	445	6·63

These studies are expected to throw light on the migration and local movement of fish, their growth, rate of exploitation and other aspects of the population dynamics.

Fisheries of the Chilka Lake

During the 12 months' period ending 31st December 1959, 37, 96, 767 kgm. (1,01,723 md.) of fish are estimated to have been captured from the Chilka lake. Of these 32·16% (1,221 metric tonnes) were prawns, 14·29% (543 metric tonnes) mullets, 13·33% (506 metric tonnes) clupeids, 11·49% (436 metric tonnes) cat-fishes, 9·96% (378 metric tonnes) threadfins, 5·78% (219 metric tonnes) perches, and 5·07% (193 metric tonnes) sciænids. August had the heaviest production when 11·5% of the year's catch, comprising 21·9% of the lake's annual prawn production, was harvested. February was the leanest month in 1959 when only 6·1% of the annual catch was made. Among prawns *Penæus indicus* and *P. semisulcatus* were the most dominant

species, the former comprising 22·64% and the latter 7·45% of the lake's total production. Within the group, these two species together made up about 89·11% of the production. *Mugil cephalus* was the most dominant species among mullets, contributing 8·78% of the lake's annual production. Among clupeids the mud shad *Nematalosa nasus* followed by *Hilsa ilisha* were the most important species caught, contributing to 4·66% and 4·57% respectively of the annual production. *Mystus gulio* was the most dominant cat-fish, contributing to 7·80% of the annual yield, followed by *Arius* sp. and *Plotosus canius*, together making up about 3·30% of the crop. Among perches *Lates calcarifer* was the most important species and made up 3·62% of the year's yield. Species of *Gerres* and *Sparus* together formed 1·27% of catch. *Eleutheronema tetradactylum* was dominant among threadfins, contributing to 10·88% of annual production and *Pseudosciæna albida* the most important among sciænids, forming 3·83%.

The data obtained regarding catches from prawn traps are summarised below:

Prawn catches-per-trap-per-day (in grams)

Month	Type of trap	Catch-per-trap-in-grams in sectors				Catch per trap in entire lake
		Northern	Central	South	Satpara	
1959—						
April ..	Baza	67	12	..	..	26
	Dhaudi	..	54	28	..	40
May	Baza	69	48	..	..	54
..	Dhaudi	..	72	101	..	100
June ..	Baza	54	36	..	..	42
	Dhaudi	..	74	154	1746	351
July ..	Baza	31	40	..	1530	205
	Dhaudi	..	28	73	1437	198
August ..	Baza	29	78	..	348	175
	Dhaudi	..	139	85	295	92
1960—						
March ..	Baza	48	21	..	156	44
	Dhaudi	..	46	..	92	78

Biological Observations on Commercial Fisheries

Mugil cephalus formed 60·23% of the production among mullets. The results obtained by tagging tend to show that one-year old immature specimens of this fish (largely females) stay in the lake. The recovery of one mature tagged *Mugil cephalus* (male) from the sea about 5 miles South-East of Chilka lake mouth confirms some of the observations made last year on seaward migration of the species. While, as in earlier years, lakeward migrating advanced fingerlings of *Mugil cephalus* entered commercial fishery in appreciable numbers in May, departmental collections made with finer meshed nets revealed the availability of smaller fingerlings (41 to 55 mm.) in February 1960. A similar occurrence of Juveniles was observed in January and February 1959. The recovery of one tagged mature *Liza trocsheli* from the sea near Chilka mouth tends to confirm the earlier observations on seaward breeding migration of the species. Further studies are in progress.

Penæus indicus formed 56·95% and *P. semisulcatus* 22·64% of the production of Penaeid prawns. The post-larvæ of both the species have been observed to enter the lake from the sea along with the tide practically throughout the year. The period of availability of large sized prawns of these species in the lake mouth regions commenced in April 1959 and extended upto September. Large prawn catches at the lake mouth centre is due to their seaward drift migration with low tide, which has a correlation with the phases of the moon, the catches being during 4 to 5 days following new moon and full moon.

Eleutheronema tetradactylum upto 100 mm. in total length feed largely on mysids (55%), amphipods (10%), isopods, Cumacea, decapod larvae, etc. The bigger size-group measuring upto 300 mm. subsists largely on prawns (48%), mysids (16%) and other fish (*Mystus gulio*, *Barbus* sp., *Thrissocles*, *Anchoviella*, etc.). The largest size-group measuring 301 mm. and above subsists on prawns (50·7%) and other fish (37%).

There is great abundance of specimens measuring 76 to 300 mm. in the commercial catches practically throughout the year, which is caused by protracted breeding with brief interruptions during the period January to July.

Sparus sarba formed 9·21% of perches landed. Tagging results have confirmed the earlier observations on breeding and migration of the species. Several mature specimens tagged near Satpara in November to December have been recovered from the lake mouth area and this confirms the view

about sea breeding of this species during November to January. Juveniles, (10 to 50 mm.) enter the lake in January to February. New recruits enter commercial fishery by April forming a peak at 83 mm. class and by October form another peak at 143 mm. class. A peak centred at 173 mm. class in February has been interpreted as that of the fish of second year.

Lates calcarifer formed 64·76% of perch catches. Specimens measuring upto 50 mm. feed mostly on copepods, decapod larvae, insect larvae, diatoms etc. Those of the size range 50 to 300 mm. subsist mainly on larger crustacea (60%) comprising prawns, stomatopods etc., and other species of fish (30%) like small clupeids, gobieds etc. (301 mm. and above). Since the fish attains very large size numerous age groups enter the commercial fishery.

Gerres setifer formed 13·5% of the annual production of perches. The juveniles of this species feed on copepods (25%), ostracods (10%) and miscellaneous matter like fragments of algæ, insect remains, etc. (32%). Adults feed on Crustacea (42%), molluscs (31%), algæ (3%), decayed organic matter (1·3%), amphipods (*Orchestia* sp., *Quadrivisio* sp.), isopods (*Synidotea, Cirolina* sp.), copepods (*Nitocra* sp., *Pseudodiaptomus*, etc.), Cladocera and Ostracoda (*Cyprts* sp.) form the important items among Crustacea. The species breeds in the lake from May to September. Fish of the year enter the commercial fishery in September, forming a conspicuous mode at 53 mm. class and attain a length of about 113 mm. by July of the next year.

Pseudosciæna coitor formed 77·9% of the catches of sciænds. A tentative analysis of age and growth from length-frequency studies shows that the young of the year enter the commercial fishery in August. One-year-old individuals appear to be centred around 300 mm. length, 2-year-old ones around 500, 3-year-old about 675 and 4-year-old and above about 800 mm. Young "Borogo" upto about 75 mm. long, feed mostly on amphipods. Bigger forms upto 275 mm. length feed on amphipods (30·6%), prawns (17·1%) and fish (12·4%). Still bigger forms subsist on prawns (46·1%), fish (22·2%), stomatopods (10·0%) and algæ (6·5%). The allied species *Sciæna russelli* feeds largely on debris, amphipods and prawns.

Mystus gulio formed 69·58% of the cat-fishes caught in 1959. This species feeds largely on amphipods which form 54·1%, 32·2% and 22·1% of the diet of small, medium and large age groups respectively. Other items of diet of small specimens comprise Cladocera (15·6%), mysids (10·9%), debris (7%), etc. Algæ (21·7%) and prawns (13·4%) appear prominently in the diet of medium-sized and fishes (17·9%) and prawns (15·0%) in that of large-sized forms.

Young *Osteogeneiosus militaris* (upto 250 mm.) subsist largely on amphipods (38·9%), arachnids (33·3%) and insects (11·1%). Bigger forms feed on lamellibranchs (29·2%), algæ (22·2%) and mud (18·5%).

Plotosus canius formed 13·81% of the cat-fishes. Specimens measuring 201 to 375 mm. thrive on prawns (20·7%) and fish (20·1%). The stomach contents of larger forms show 26·4% debris, 20·7% prawns and 16·3% lamellibranchs.

Tachysurus arius formed 15·59% of the annual production among cat-fishes. Very young fish (upto 100 mm.) feed exclusively on debris. Older forms (upto 276·0 mm.) show 23·6% debris, 23·5% prawns and crabs and 12·6% amphipods in their stomachs. Still bigger forms show 18·3% debris, 15·3% lamellibranchs, 15·1% prawns and 9·2% fish.

Physico-chemical Features of the Chilka Lake

Observations on water and air temperature, transparency, pH, salinity, total alkalinity, dissolved oxygen, silicates, phosphates, iron and nitrates were continued throughout the year at six centres of the lake. Water temperatures ranged from 21·4° C. (January) to 30·3° C. (June) and pH varied from 8·1 to 8·6. Salinity varied in the main body of the lake from 4·5‰ to 27·94‰, highest value being in June and lowest in September. The lake mouth centre showed 0·66‰ salinity in October and 34·8‰ in April. Alkalinity was of the order 98·5 p.p.m. in March and 59·6 p.p.m. in September; D.O. varied from 4·6 p.p.m. to 6·9 p.p.m.; silicates from 0·92 p.p.m. to 4·1 p.p.m.; phosphates from 0·002 p.p.m. to 0·2 p.p.m.; Iron from 0·005 to 0·064 p.p.m. and nitrates from 0·05 to 0·103 p.p.m.

Fish Pathology Investigations

Studies on Fish Mortality in Jute-retting Tanks

A fresh series of experiments were initiated during the year in the experimental tanks of the Jute Agricultural Research Institute. Significant differences in the plankton production were observed and it appears that these have a direct bearing on the quantity of jute used for retting. Laboratory experiments using fingerlings of major carps and small pieces of the two species of jute plants were undertaken at Nilganj and Barrackpore. A few more observations are to be made during the next jute season of 1960.

Studies on Fish Diseases and Mortality

Detailed investigations on an eye-disease which caused extensive mortality of *Catla catla* were made during the later half of the year. This

disease, prevalent in many areas of West Bengal, was specific to *Catla catla*, affecting the eyes only, which in the earlier stages of infection became reddish and later changed to an opaque milky white nature. Eventually the eye got petrefied completely, leaving a punctured cornea or only the hollow eye cup. It was found that a bacterium and an actinomycete were responsible for the disease.

Group treatment for the above disease was tried in five fishery tanks and a minimum of Rs. 35,000 worth of fish were saved. It was noticed that provision of high dissolved oxygen content, removal of decaying matter and disinfection with dilute potassium permanganate solution (upto 0·5 p.p.m.) were effective in preventing the spread of the disease.

Investigations on "Exophthalmus" and "Dropsy" were also conducted during the year under report. Co-existence of these two diseases in major carps was a noteworthy feature. Preventive methods for "Dropsy" were tried and it was possible to save fishes valued at about Rs. 10,000 in a Jheel near Barrackpore.

Incidence of tumour disease in a big stock of Gold fish was investigated and control experiments using antibiotics and sulpha drugs have been taken up.

A preliminary survey of *Ligula* infection in Tilaya and neighbouring areas was made in August and necessary biological data on the parasites, as well as their hosts have been collected. Since the life-history of the parasite is not known, attempts are being made to collect the adults from water-birds and the first stages from planktonic copepods.

Investigations on Parasites of Hilsa

Detailed investigations on parasites may reveal the migratory routes of the hosts and also knowledge about raciation. With this end in view studies on the parasites of *Hilsa ilisha* have been initiated.

Miscellaneous Studies

In view of reports received about the large-scale destruction of wooden fishing implements by the action of aquatic wood-boring organisms in Chilka Lake, an investigation into this problem was considered worthwhile. Data on the concerned organisms and the intensity of their attack in the lake mouth area and the entire stretch of the outer channel have so far been collected.

Investigations were made on large-scale fish mortalities reported in several stocking tanks at Barrackpore, Pulta, Nilganj, Shamnagar, and Calcutta and suitable control methods were suggested to the owners.

A series of experiments on the use of tea-seed powder, seeds of wild poppy and some indigenous plant barks as fish poisons was taken up and the data obtained are being analysed.

As Chandigarh Lake fishery is reported to be affected by high turbidity, a series of laboratory experiments and spot surveys were conducted with a view to evolve a suitable solution to the problem. A preliminary report on the problem and a pilot scheme to clear the water have been prepared.

Encouraging results have been obtained from preliminary experiments on the use of silkworm pupæ as artificial food for carp fingerlings.

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CONTENTS

PAGE

Venkataraman, G. Studies on the Food and Feeding Relationships of the Inshore Fishes Off Calicut on the Malabar Coast 275

Subrahmanyan, R. and Viswanatha Sarma, A. H. Studies on the Phytoplankton of the West Coast of India. Part III. Seasonal Variation of the Phytoplankters and Environmental Factors 307

Jones, S. Notes on Eggs, Larvae and Juveniles of Fishes from Indian Waters. VI. Genus *Auxis* Cuvier. VII. *Sarda orientalis* (Temminck & Schlegel) 337

Kaikini, A. S. The Fisheries of Malwan 348

Jones, S. and Silas, E. G. Indian Tunas—A Preliminary Review, with a Key for Their Identification 369

Rama Sastry, A. A. and Ramamritham, C. P. Velocity of Sound in the Arabian Sea along the South Malabar Coast during the Post-monsoon Season 394

Balasubramanyan, R., Satyanarayana, A. V. V. and Sadanandan, K. A. A Preliminary Account of the Experimental Rock-lobster Fishing Conducted along the South-West Coast of India with Bottom-Set Gill Nets 407

David, A. and Roy, P. Some Measurements of Toxicity of Tannery and Textile Wastes and Their Components to Fish by Bio-assays . . . 423

Kamasastry, P. V., Studies on the Indian Sardine Oil 443

Kuriyan, G. K. and Radhalakshmi, (Miss) K. A Comparative Study of Certain Characteristics of the Common Vegetable Fibre Twines for Fishing Nets 448

Deshpande, S. D. On the Comparative Catch Efficiency of Hand-operated and Winch-operated Trawls 458

Kuriyan, G. K. and P. J. Cecily, (Miss) The Common Characteristics of Cotton Fishing Net Twines Experiment Series. II 471

Satyanarayana, A. V. V. Preliminary Studies of Certain Characteristics of Spherical Fishing Floats 483

Government of India, Central Marine Fisheries Research Station, Marine Fisheries P.O., Mandapam Camp, South India—Annual Report of the Chief Research Officer for the Year Ending 31st March 1960 . . 496

Government of India, Annual Report of the Central Inland Fisheries Research Station, Barrackpore, for the Year 1959–60 553

The drawing on the Cover Page depicts a tuna fishing scene off the island of Minicoy. The oceanic skipjack, Katsuwonus pelamis (*Linnaeus*) *which forms the most important fishery there is shown in the inset below.*

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